POWER

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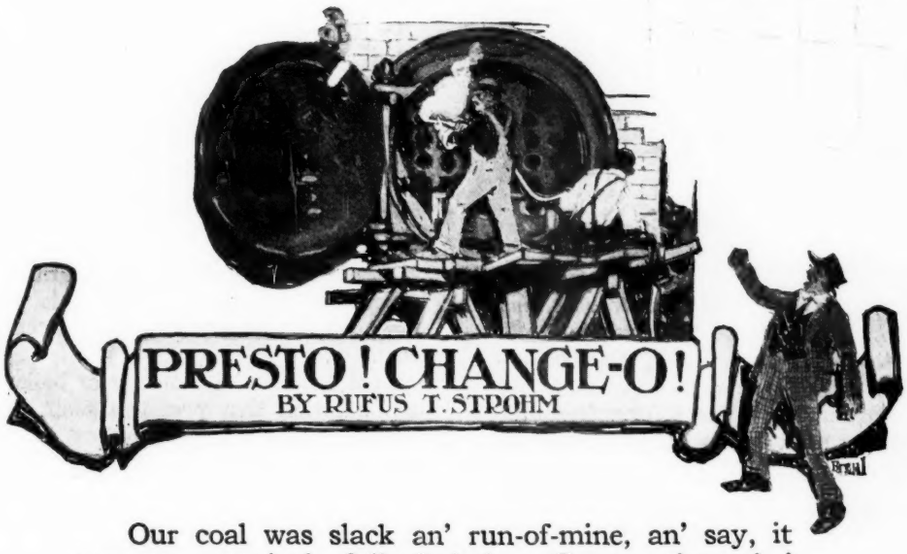


Our coal was slack an' run-of-mine, an' say, it sure was gassy! As full of pitch as Georgy pine. An' smoky? Lawd 'a massy! The way it cluttered up them tubes was surely somethin' frightful, an' in the boiler room us boobs got mighty peeved an' spiteful.

The boiler wasn't none too high, which sorter cramped the furnace; but no wise geezer drifted by to show us or to learn us. An' so the sooty gases riz an' through the boiler floated, an' everywhere they hit, they friz, until the tubes was coated.

Then there was merry hell to pay! The pressure got to droppin' in spite of the unceasin' way us fellers kept a-hoppin', until the chief instructed us to give the tubes a' cleanin'—his language bein' mostly cuss, but mighty plain of meanin'.

We rigged a scaffold out of plank an' got the steam lance goin', an' cussed the blank-star-double-blank-three-daggers job of blowin'. We couldn't make the stuff stay put for half a minute, brother; for when one tube was clean, the soot went settlin' on another.

But that was in the early days before our eyes was open. We've canned them foolish, ancient ways, the swearin' an' the mopin'. For blowin' soot's so easy, now, there's hardly nothin' to it; it's almost sinful, I allow, to take good pay to do it.

We take a firm an' steady grip upon a valve an' turn it, an' just about as quick as zip! that soot is gone, gol durn it! Today our jobs is fit for gents an' all our costs is lower, an' everybody's happy sence the boss installed a blower.

EFFICIENT OPERATION

By John D.

Many engineers do not take the trouble and others do not know how to keep records that will enable them to obtain the most efficient boiler-room operation. This article, in text and tables and by numerous curves, gives information that should enable any engineer to get the most out of his boiler plant.

FEW engineers have really kept pace with the economic trend of events that have taken place in the boiler room, and the direct result of this has been a high cost of power due to a waste of coal. Few people realize the importance of the coal question, but everyone is alive to the fact that the price of coal is advancing, partly due, no doubt, to the increased cost of mining, but also partly due to the rapid using up of the most easily mined coal beds.

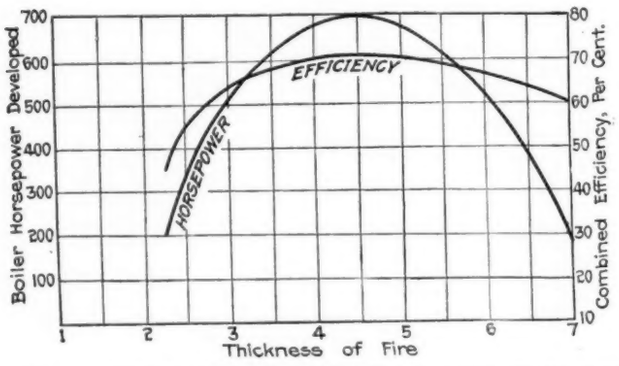


FIG. 1. CURVES SHOWING EFFECT OF FIRE THICKNESS

Therefore engineers, wherever possible, should prevent the waste of coal in the boiler rooms of small and large power stations. Table I shows the percentage cost of power chargeable to the boiler room. This table is based on the generating cost per kilowatt-hour as 100 per cent. It will be seen that the average boiler-room cost will run very close to 85 per cent of the total cost of power.

Does it pay to devote time and thought to the boiler room? The answer is found in Table II. During the year *A* no great care was given the boiler room; that is, no one man has been detailed to keep a close watch on it. But in the year *B* such a man had been made responsible for this work. This table very clearly shows that it does pay to give attention to the boiler room.

Final commercial economy of boiler operation is the next question that presents itself. I think that Mr. Polakov has given us the best possible formula, or equation; namely, that $Es = Ef \times Ep \times Em \times Eg \times Ec \times Et$, in which E indicates the ratio of utilization or efficiency and the corresponding indexes signify as follows: s = steam generation, f = financial outlay, p = purchase of fuel, m = attendance of men,

TABLE I. PERCENTAGE COST OF POWER CHARGEABLE TO THE BOILER ROOM

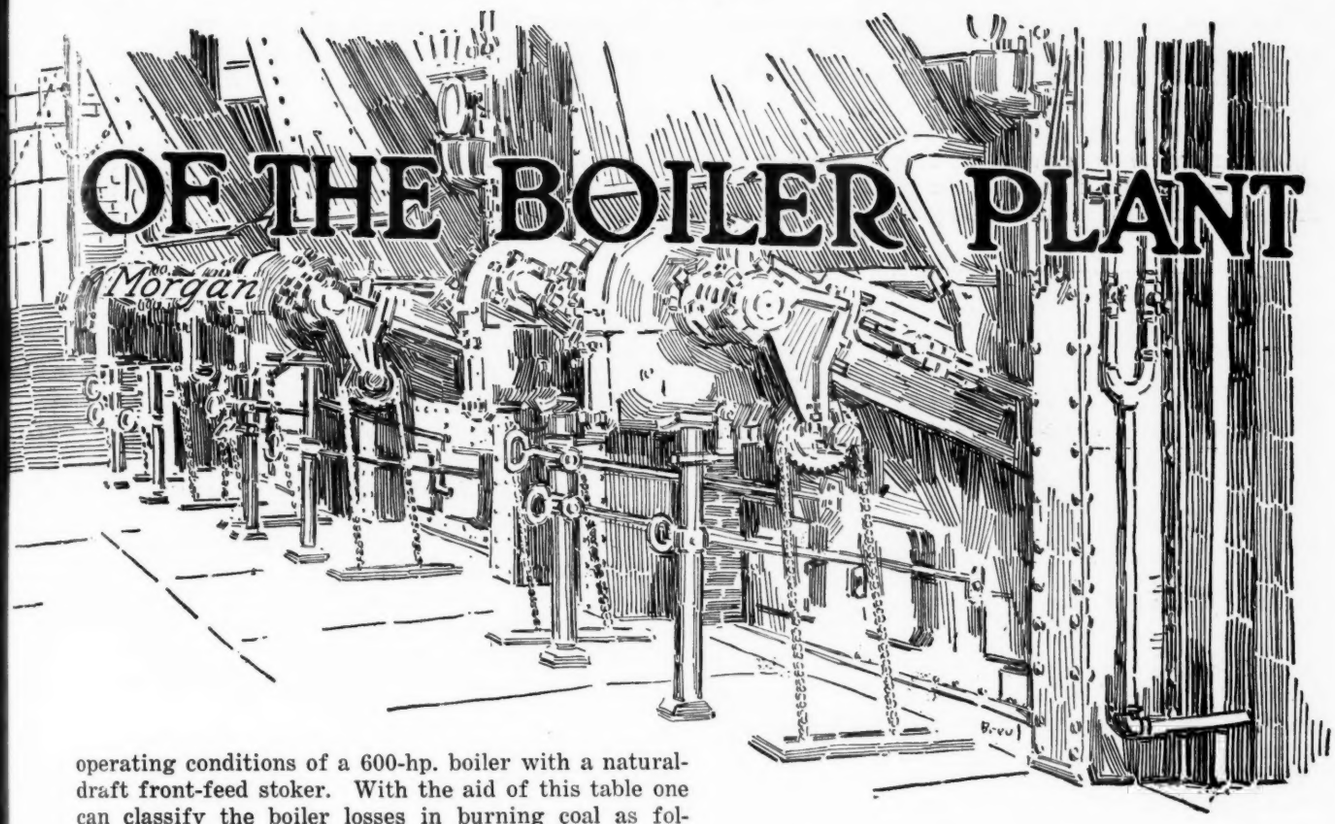
	Plant A	B	C	D	E
Total kw.-hr. output	95,403,319	120,349,670	33,246,600	47,875,967	233,015,000
Lb. of coal per kw.-hr.	2.72	2.81	3.004	3.517	2.443
Cost of coal per 2000 lb., dollars	2.38	2.377	2.32	1.61	2.715
Comparative total cost per kw.-hr., per cent	111.7	116.3	109.4	138.8	100
Coal cost, per cent	64.158	63.188	70.648	44.765	77.453
Water cost, per cent	1.98	6.273	0.202	2.011	0.709
Boiler-room labor, per cent	7.920	8.555	9.109	14.698	4.673
Boiler-room maintenance labor, per cent	2.376	2.281	0.809	1.165	1.107
Boiler-room maintenance material, per cent	2.376	6.273	1.417	2.170	3.610
Total per cent cost in boiler room	78.810	86.570	82.185	64.809	87.552

g = gasification of fuel in furnace, c = combustion of gases, and t = transmission of heat of gases to the boiler water and steam.

Of all the foregoing modifiers only that of the financial outlay lies beyond the power of the operating engineer; therefore it has been disregarded in this discussion.

At this point it might be well to consider the approximate loss per pound of fuel burned in a well-operated power plant. Table III is based on the actual operation of a plant, and wherever the losses could not be accurately determined they were calculated with care. This table is used only to indicate where the possible losses occur and in what relative proportion.

It will be seen that a total loss of 24.5 per cent occurs in the boiler room. This naturally raises the question, Where do these losses occur? In the boiler and furnace or in the plant as a whole? This can be partly solved by making up a heat-balance table for the boilers, which will show the relative losses. An example is given in Table IV, which is based on actual



OF THE BOILER PLANT

operating conditions of a 600-hp. boiler with a natural-draft front-feed stoker. With the aid of this table one can classify the boiler losses in burning coal as follows: (1) Loss in dry chimney gases; (2) loss due to incomplete combustion; (3) loss of fuel through grates; (4) superheating moisture in air; (5) moisture

TABLE II. RESULT OF CARE IN THE BOILER ROOM

	Year A	Year B	Per Cent Increase	Per Cent Decrease
Net kw.-hr. generated	233,015,000	271,732,000	16.616	.....
Lbs. of coal per kw.-hr.	2.443	2.210	.....	9.537
Cost of coal per 2000 lb.	2.715	2.783	2.505	.....
Boiler-room labor cost, per cent	4.673	4.187	.....	16.587
Coal cost, per cent	77.453	76.260	.....	8.321
Water cost, per cent	0.709	0.666	.....	12.50
Boiler-room maintenance labor, per cent	1.107	1.142	.....	4.0
Boiler-room maintenance material, per cent	3.610	3.330	.....	14.11
Relative total cost per kw.-hr.	100	.93	.....	6.888
Net thermal efficiency, per cent	10.18	11.31	11.1	.....

in fuel; (6) hydrogen in fuel; (7) soot and smoke; (8) radiation and minor losses.

Having located the possible boiler losses, there yet remain the losses of the boiler room at large. These are as follows: (1) Purchase of unsuitable coal; (2)

TABLE III. FUEL LOSSES AND THEIR RELATIVE PROPORTIONS

	Per Cent
Combustible matter in ash	2.5
Radiation and leakage of boiler	14.0
Gases rejected to chimney	5.0
Blowoff losses	1.5
Radiation and leakage of steam piping	1.5
Friction loss in auxiliaries and turbines	2.0
Rejected to condenser	58.0
Electrical losses	1.2
Required for auxiliaries	6.5
Total loss	92.2
Regained from condensate and exhaust steam	4.0
Total per cent delivered to bus	11.8

weathering of coal in transportation and in storage; (3) poor feed-water temperatures; (4) labor conditions; (5) maintenance; (6) unsuitable boiler-room record sheets.

Naturally, in considering these items one must have reliable data on the condition of the boiler room as a whole. This can be obtained only by an actual test, and therefore the first point of operating a boiler room efficiently must be that of a test on the whole plant. This does not mean a highly specialized testing equipment commonly known as a laboratory test, for the general results given in such reports are a mass of highly calculated data and have little or no bearing on the actual operating boiler conditions. What is favored is a continuous boiler-room test using the following instruments: An open feed-water heater with a metering device of tested accuracy; water-flow meters on the boiler-feed pumps; standard meter on the makeup line; steam-flow meters on the main steam lines and one for moving from boiler to boiler; reliable scale for the coal used; recording temperature gage on the steam header, blowoff and feed-water line; recording pressure gage on the steam and feed lines and good thermometers on

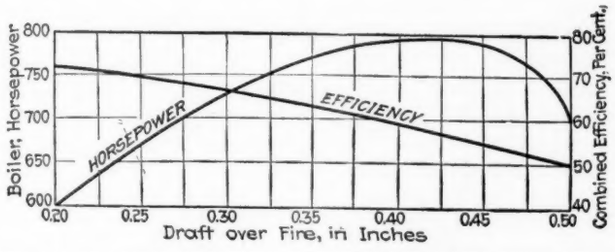


FIG. 2. CURVES SHOWING EFFECT OF DRAFT OVER FIRE

the open feed-water heater. If these instruments are properly used, a continuous test on the boiler room is possible.

The next important action to be taken is that of making an actual test on each type of boiler and stoker in the plant so that the present operating conditions may be known. This test should be reported graphically, as it is then possible to see at a glance the effect of various items on the boiler and furnace efficiency. Figs. 1, 2 and 3 illustrate the graphical method of reporting boiler tests by means of plotted curves. The next point in order is to run a series of tests to

determine the right kind of coal for the various boilers. An example of such a test is given by Table V.

It must be remembered that each plant will have special operating features and that they must be treated as important factors, but in general when the following items have been determined or computed, a true answer can be made regarding the right kind of coal: British thermal units per dollar; coking features of

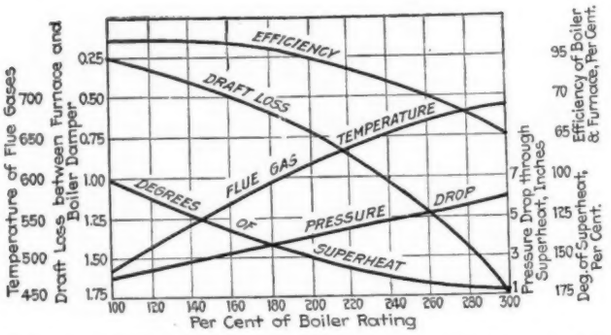


FIG. 3. OPERATING CURVES OF WATER-TUBE BOILER

the coal; nature of ash; smoking characteristics; labor involved in burning; efficiency of boiler and furnace; effect on boiler maintenance; possibility of obtaining a stable supply; amount of storage loss.

When the proper coal has been found, the remainder of the trouble experienced in efficient boiler-room operation becomes simply a problem of boiler operation.

Suppose that sufficient records have been obtained from the daily station tests to enable one to study them in a thorough manner. The first thing that will come to mind is, What is the typical load curve for each day? This can easily be determined from the readings

TABLE IV. HEAT-BALANCE TABLE SHOWING RELATIVE LOSSES

	Per Cent
Heat absorbed by boiler	77.50
Heat lost by moisture in coal	0.15
Heat lost by hydrogen in coal	4.40
Heat lost to chimney	12.00
Heat lost by moisture in air	0.25
Heat lost by carbon monoxide	0.80
Heat lost by carbon in ash	2.08
Heat lost by radiation (by difference)	2.82

and charts, although it must be remembered that the chart obtained from the open feed-water heater does not always indicate the true boiler-room load curve, for the rate of feeding will influence this item to a marked degree; but if the station steam-flow chart is used, it can be readily calculated and upon the determination of this fact a suitable load-curve chart can be made up and upon this chart can also be plotted the boiler hours in service. As a rule a valuable bit of information can be gathered from this chart.

The information obtained can be used in the issuing of a boiler-load chart which will show the boiler operator the proper number of boilers to be carried on the line and also the number of boilers needed for stand-by use. An example of such a chart is given in Fig. 4.

Having a definite plan in operation regarding the number of boilers to be carried on the line, the question of banking boilers arises. This matter has, as a rule, been given little or no thought in the average boiler room, and naturally, the first question asked is, How much coal does it take to properly bank a boiler? Table VI shows the amount of coal needed for various types of boilers and stokers. The figures given are the result

TABLE VI. AMOUNT OF COAL NEEDED FOR BANKING

Name of Boiler and Stoker	Normal Boiler Rating	Lb. of Coal per Hour	Lb. of Coal per B.-Hp.
B. & W. boiler, Roney stoker	600	162	0.270
B. & W. boiler, Bayonne stoker	600	201	0.334
Edge Moor, hand fired	600	115	0.192
Heine, hand fired	300	53	0.177
Stewart, hand fired	150	19	0.127

of tests that were made over a long period, but no experiments were made to determine the proper method of banking. That is, the boiler was banked as it had always been.

Later, a test was made on the first boiler, and by trying different methods it was found that by banking the boiler in a scientific manner 100 lb. per hour, or 0.166 per boiler-horsepower, was sufficient. This same test also determined that it took an additional 1,500 lb. of coal to bring the boiler up to a steaming rate of

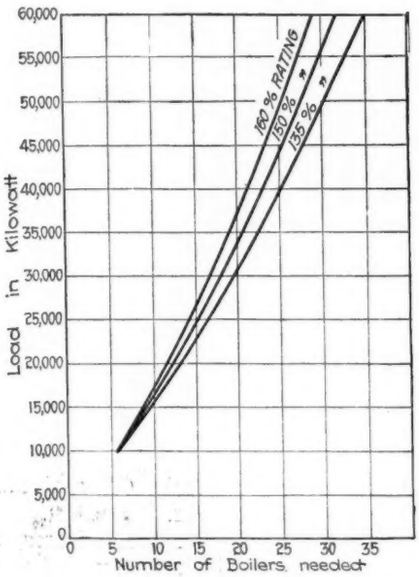


FIG. 4. CURVES SHOWING NUMBER OF BOILERS IN SERVICE FOR VARIOUS LOADS

100 per cent. In general it will be found, when conducting such a test, that the results obtained for the first five hours are not reliable because the walls of the furnace give off the heat stored up in them. In general, the following rules should be adopted in banking boilers: Have seal plates made to seal up the hopper; install a tight-fitting damper; see that there

TABLE V. TEST ON TWO 94-HP. RETURN TUBULAR BOILERS

Draft	Natural	Natural	Natural	Parsons' Blower	Parsons' Blower	Parsons' Blower	Parsons' Blower	Parsons' Blower	Parsons' Blower
Kind of coal	Buckwheat	Buckwheat	Buckwheat	Buckwheat	Buckwheat	Buckwheat	Bird's-eye	Bird's-eye	Bird's-eye
Steam pressure	85	85	85	90	90	90	90	90	90
Temp. of feed water	198	200	200	192	192	192	186	187	185
Equiv. evap. from and of 212° F.	9.15	9.19	9.18	9.30	9.45	9.62	8.53	8.38	8.44
Hp. developed	140	142	140.5	160	155	148	152	152.5	154
Steam for steam jets, per cent				8.52	6.89	4.86	5.36	5.25	5.68
Cost of 1 hp., inc. jets, cents	0.5179	0.5158	0.5163	0.5611	0.5387	0.5179	0.448	0.4557	0.4538
Evap. per lb. of combustible	10.45	10.63	10.43	11.06	11.03	11.24	10.29	10.07	10.00

Price of buckwheat, $2.75. Price of bird's-eye, $2.10. Heating surface, 1405. Grate surface, 33.

ere no air leaks in the setting, and do not bank the boiler too soon.

Naturally, many engineers will ask why such stress is laid on the banking of a boiler. This is because in a majority of plants the coal used for banking will run very close to 4 per cent of the total coal used, and this at best is a large, unavoidable loss, and it pays to give attention to this item, for every pound of coal saved by proper banking is a clear gain in the economic operation of the plant.

The next important item to be attended to is that of the boiler settings. This matter many engineers fail to consider of importance. There is no excuse for leaky boiler settings, for a few hours' work of a handy man with asbestos cement will eliminate this serious boiler-room loss.

The question of draft can be solved by a boiler test made so that it will show the effect of various drafts on the boiler operation. This test should also show the draft loss. Table VII illustrates the value of such tests made on two boilers supposedly identical, and Fig. 5 is a curve sheet which shows the effect of draft on the capacity of a 600-hp. boiler with a chain-grate stoker.

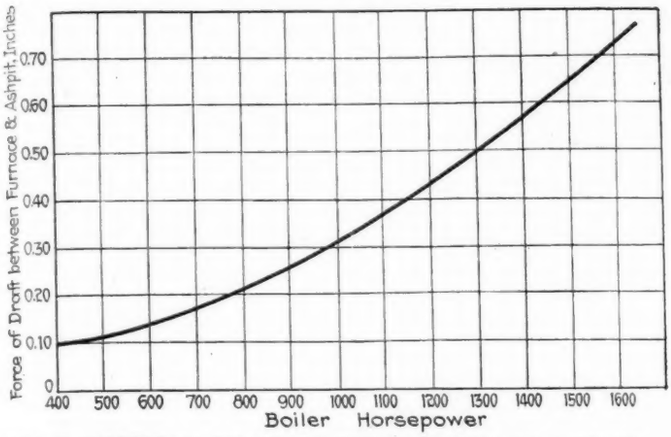


FIG. 5. EFFECT OF DRAFT ON THE CAPACITY OF A 600-HP. BOILER, NORMAL RATING, AND EQUIPPED WITH A CHAIN-GRATE STOKER

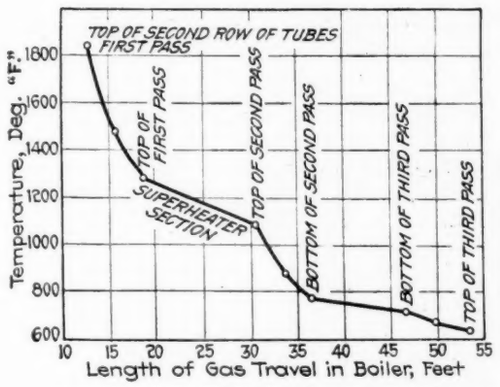


FIG. 6. TEMPERATURES OBTAINED AT VARIOUS POINTS IN 600-HP. BOILER SETTING

The draft conditions of plants are varied, but in general the following items affect it: Height of chimney or stack; tightness of flues; number of bends in the flue and heat insulation of the flue and economizer settings. In the boiler proper the draft loss will depend largely on the height and spacing of the tubes, soot and ashes on the tubes, and on the boiler design and baffles. In the fuel bed the draft losses will be in some proportion to the size of coal, shape of pieces, nature of firing and the nature of the ash and grate construction. Very few designing engineers have devoted much of their time to the draft problem. When it is attacked in a thorough manner, its solution is quite simple. The heat drop through a boiler is an item of importance to the economic operation of the plant, and its determination is a simple matter, as only an electric pyrometer with several leads is required. To some this test will seem superfluous, nevertheless it shows the condition of the baffles and where the greatest heat drop occurs. To illustrate the value of such a test, two curves, Figs. 6 and 7, are used which show the temperatures obtained in two hand-fired water-tube boilers.

Everyone realizes the importance of baffles in relation to boiler-room economy. In most cases the manufacturer has properly located his boiler baffles, but in some instances it has been found advisable to move them, owing to the restricted flow of gases. The necessity for this change can be readily ascertained by making a test on the draft and temperature conditions of the boiler at various ratings. The construction of the baffle is important and should be given close attention. The best possible baffle construction is obtained when two courses of baffle brick are used with a ½-in. sheet of asbestos millboard between the courses. This baffle is easily constructed and repaired.

In the last few years some experiments have been made on the concrete baffle, but its success has been seriously questioned. The plastic asbestos baffle has

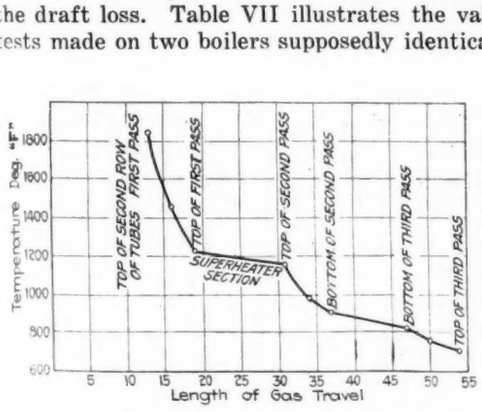


FIG. 7. TEMPERATURES OBTAINED IN 600-HP. BOILER SETTING

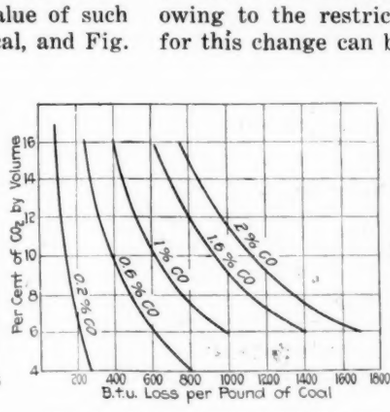


FIG. 8. B.T.U. LOSS DUE TO INCOMPLETE COMBUSTION

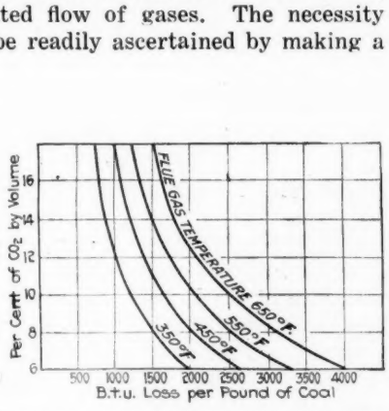


FIG. 9. B.T.U. LOSS DUE TO HIGH TEMPERATURE OF CHIMNEY GASES

been tried with varying success, but in most places where high ratings are used, this type has been found unsuitable for the front baffle, although it does give fairly satisfactory service in the second and third baffles.

The design and construction of the furnace depend largely on the method of firing and also on the rate of combustion. But recent experiments have shown that the design of the bridge wall has a marked influence on the life of the furnace and also on the efficiency of combustion; marked success has been experienced in the use of curved bridge walls. The best form of arch can be obtained only by a series of experiments because each type of boiler and furnace will require a different form. In the construction of the furnace, bricks of a poor quality but uniform as to size will outlast bricks of good quality but not uniform. In all cases bricks entering into the construction of a furnace should be

TABLE VII. EFFECT OF DRAFTS ON BOILER OPERATION

600-Hp. B. & W. Boilers, Westinghouse Underfeed Stokers	Boiler No. 1	Boiler No. 3
Average steam pressure	203.00	200.00
Average boiler horsepower	728.00	947.00
Pressure in ashpit, in. of water	2.73	2.65
Draft, inside damper, in.	0.745	0.815
Draft, overfire, in	0.048	0.119
Drop from fire to soot chamber, in.	0.697	0.696
Draft at second row of tubes, first pass, in.	0.065	0.119
Draft at middle of first pass, in.	0.075	0.156
Draft at top of first pass, in. (superheater located here)	0.092	0.171
Draft at top of second pass, in. (superheater located here)	0.265	0.342
Draft at middle of second pass, in.	0.313	0.414
Draft at bottom of second pass, in.	0.423	0.511
Draft at bottom of third pass, in.	0.440	0.531
Draft at middle of third pass, in.	0.509	0.592
Draft at top of third pass, in.	0.565	0.638
Per cent drop from fire to bottom at first pass, per cent.	2.44	
Per cent drop from bottom to middle of first pass	1.43	5.32
Per cent drop from middle to top of first pass	2.44	2.15
Per cent drop from top of first to top of second pass	6.36	7.47
Per cent drop from first to second pass	24.8	24.6
Per cent drop from top of second pass to middle of second pass	6.88	10.35
Per cent drop from middle of second pass to bottom of second pass	15.8	13.93
Per cent drop from fire to bottom of second pass	53.7	56.35
Per cent drop from bottom of second pass to bottom of third pass	2.44	2.87
Per cent drop from bottom of third pass to middle of third pass	9.9	8.76
Per cent drop from middle of third pass to top of third pass	8.04	6.61
Per cent drop from fire to top of third pass	74.2	74.6
Per cent drop from top of third pass to damper	25.8	25.4
Per cent drop from bottom of first pass to top of second pass	28.7	32.1
Per cent drop from top of second pass to bottom of third pass	25.1	27.2
Per cent drop from bottom of third pass to top of third pass	17.95	15.4

gaged, and if they vary one-eighth inch from the specified size, they should be rejected. In many cases the use of a high-temperature cement will be found of value. It is advisable to have a complete set of drawings for each size of brick used in furnace construction so that when ordering bricks the manufacturer can be furnished with one. This will obviate any confusion in regard to sizes. Table VIII shows the approximate melting points of various bricks.

Fuel-siftings loss is one of importance and is quite an item in the average plant. To avoid this loss is a problem of mechanical operation, as for instance, the installation of a siftings hopper and bucket conveyors for sending the siftings back to the boiler or coal bunker. When burning coal containing a large amount of siftings, it should be sprayed with water; it will be found that an increased efficiency can then be obtained. There is a small loss in burning wet coal, but as this is only about 1 per cent for an addition of 10 per cent moisture, the gain obtained from the better coking features will more than offset the loss due to moisture. There is also a loss caused from superheating the moisture in the air admitted to aid combustion, but it is a small one, and in plants where the economic operation of the boiler room has been reduced to the point of considering this item, it has been taken care of by piping the exhaust air from the generators to the intake of the blower fans.

The smoke loss is of vital importance, not so much, perhaps because of the economic loss in the burning of

TABLE VIII. APPROXIMATE MELTING POINTS OF VARIOUS BRICKS

Nature of Brick	Melting Point, Deg. F.	Nature of Brick	Melting Point, Deg. F.
Fireclay	3000	Kaolin	3150
Bauxite	2900-3200	Bauxite Clay	3250
Silica	3100	Alumina (Pure)	3650
Chromate	3700	Chromite	3950
Magnesia	3900	Silica (Pure)	3175

coal as because it is a bone of contention between the company and the people living in the vicinity of the plant. Nowadays a city of any importance has its smoke-abatement commission. The economic loss will seldom run over 1 per cent.

It might be well, however, to consider some of the general methods of smoke abatement. Where hand-fired boilers are used, the installation of stokers will aid, but it must be remembered that a properly designed and well-operated furnace will burn coals without smoke up to a certain predetermined rate of combustion, but when this point is passed smoke will issue owing to the lack of furnace capacity to supply air and mix the gases. In a hand-fired furnace the rate of firing should be frequent, and often with a short period of air admission after firing. The use of small sizes of coal will result in less smoke. Keep down the CO, for as the percentage of CO increases so does the black smoke.

The loss due to incomplete combustion of coal is somewhat vague, but if we change it to read loss due to presence of CO, then one readily sees its direct bearing on efficient operation. Many believe that all the loss due to incomplete combustion can be laid to CO, but I have many reasons to believe that the CO is not directly responsible for all the loss, but rather, that it is simply a good danger signal for some other loss. To confirm this belief one has only to run a series of boiler tests and to see that an advance of 0.2 per cent will produce a loss in efficiency of about 4 per cent, which is slightly more than four times the theoretical loss due to such an advance. This point could be more fully explained if some of our experimental laboratories would conduct some research work

TABLE IX. EFFECT OF SOOT ON BOILER TUBES

	First Series	Second Series	Third Series
Equivalent evaporation from and at 212 deg. F. per lb. of dry coal	6.2	7.04	6.23
Dry coal per sq.ft. of grate surface per hour	13.40	9.09	13.40
Temperature of escaping gases	62.70	5.46	6.98
First series, 5 days. soot allowed to remain on tubes.			
Second series, 5 days, tubes cleaned each morning.			
Third series, 5 days, soot allowed to remain on tubes.			
Increase in evaporation due to clean surfaces, per cent			13
Decrease in coal burnt per sq.ft. of grate per hour, per cent			32.16
Lowering of stack temperature due to clean surfaces, per cent			17.59

along these lines. Fig. 8 illustrates the theoretical rate of loss due to CO for a semi-bituminous coal of 14,098 B.t.u.

The loss in efficiency due to chimney gases is so well known that it is only necessary to briefly state the general causes of high flue-gas temperatures, which are: Excess air; percentage of boiler rating; bad baffles and soot and ashes on boiler tubes. To illustrate the loss, the curve, Fig. 9, shows the percentage of loss due to high flue-gas temperature for a semi-bituminous coal of 14,098 B.t.u.

The loss due to smoke, soot and ashes on the boiler tubes can be no better shown than by Table IX, which shows the result of tests made by the University of Illinois.

Since it is necessary to clean tubes, the question arises as to what method should be used? The best method is by the installation of a mechanical soot blower using steam at boiler pressure. The next best is that of dusting the tubes with steam by means of a dusting nozzle using steam at boiler pressure. This last-named way is satisfactory if the tube blower can be made to perform his duties in a thorough manner, but vigilance must be exercised if this method is used.

The most satisfactory arrangement is that of a ratchet chronometer valve on each boiler to which should be attached a rope for operating it, and a 1-in. pipe run down to the middle point of the side wall with a connection on the end for attaching the blowing hose or pipe. The blowing member should be made of ¾-in. pipe in four sections each 4 ft. long. These sections should be jointed together by means of a metal toggle joint, the end section being equipped with a piece of pipe 6 ft. long with a dusting nozzle on one end.

Tubes should be blown twice a day where the boilers are run continuously at high ratings and once a day under normal operation.

On the Road with the Refrigeration Troubleman

By J. C. MORAN

He is called to a plant where it is impossible to get a suction pressure of more than 15 in. vacuum unless the compressor is run very slowly. An oil separator in the suction line was the source of the trouble, as it had not been properly cared for. On the next job a pipefitter causes no end of trouble in midsummer. The symptoms of these troubles, how they were located, and what was done to overcome them are well told by the troubleman.

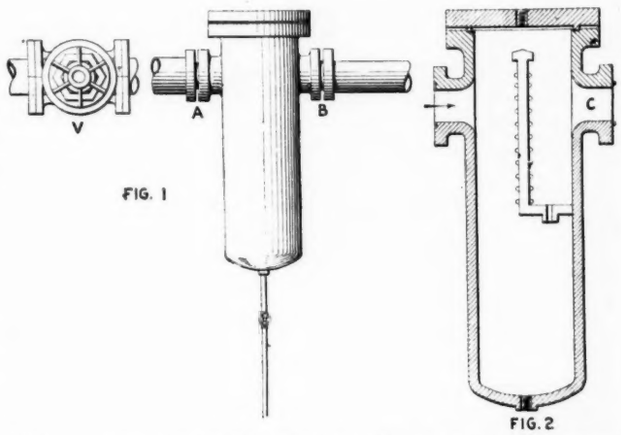
WE HAD installed a 100-ton plant in a manufacturing establishment for air-cooling purposes, and it had been in operation for about a year when we got a rush call to come out and see what had happened to it. The crew could not get the plant to work at all. I arrived on the job by the first train and found the plant shut down and everybody running around in circles.

The engineer had stopped operation the day before and pumped the plant down to make a repair on the suction line between the machine and the coolers. After he had pumped about 25 in. vacuum two or three times, the steamfitters tried to open the line at one of the joints and found that there was still considerable pressure on it. So the engineer pumped it down a couple of more times, and finally kept the machine running slowly to hold the vacuum at this point while the men broke into the line. When they tried to open the joint under these conditions, there was still a strong pressure on the line. It was getting late in the day, and the engineer decided they had better give it up for a bad job and let it go until some other day.

Then the queer thing happened. It was impossible to get a suction pressure of much above 15 in. vacuum unless the machine was run very slowly. No matter what they did with the expansion valves or anything else, it did not make any difference. The room temperatures kept going up, and there were many complaints about high room temperatures because it was a hot day in midsummer.

On going over the entire plant in a rather hurried inspection, I could find nothing wrong. I experimented with the expansion valves until they were open several turns, but without improving things. So I began to look for obstructions in the pipe lines.

I suspected the trouble might be in a suction stop valve located about 25 ft. back from the compressor in the suction line. I tried to remove the bonnet and changed my mind in a hurry. There was considerable pressure on the valve. It was plain that the trouble was at some place nearer the compressor. The next joint was where an oil and scale separator was located in the line. Fig. 1 shows the connections. I first tried to open the joint at *A*. The pressure was high at this place. So I tried another joint between the oil



FIGS. 1 AND 2. THE OIL SEPARATOR WAS FILLED WITH FROZEN OIL AND SCALE

separator and the compressor. Here I found a vacuum on the line. It must be remembered that the machine was turning over slowly and holding about 15 in. vacuum on the line.

There was only the joint at *B* on the oil separator left for me to try, and I next tried opening it. Here also there was a vacuum. It was then plain that the trouble was between the two flanges *A* and *B*, and likely some place in the oil separator. It seemed impossible to pump the line out, so I went back to the valve *V* in the illustration and shut it off tight. The flanges at *A* were then opened to let the ammonia blow until the pressure was gone. As soon as it was safe we took the cover off and examined the separator.

It took but one look to ascertain what was the trouble. A cross-section of the separator is shown in Fig. 2. The entire separator was filled with heavy oil and

foreign matter which had frozen together into a solid mass that had entirely plugged the outlet at *C*, which was the side that connected to the compressor. We had to play a steam hose on the separator for about half an hour before we could get the stuff soft enough to dig out.

When the engineer had started to pump out the system, there was probably a considerable amount of liquid ammonia in the separator. When the pressure was pumped down to 25 in. vacuum, this ammonia liquid began to boil out, and at this pressure the temperature was probably somewhere around 75 deg. below zero. This froze the oil and other contents of the separator into a solid mess, and as only very little gas was coming through the separator at the finish of pumping down, it dragged the mess into the outlet *C* and finally froze it solid. At least that is what I concluded. It might have been that a chunk of the mixture was blown up and settled into the outlet *C* at one time, and thus shut off the flow.

Of course the engineer had no one else but himself to blame for the trouble. Scale and oil traps in the suction line should be blown as regularly as the oil trap in the discharge line. It may not be required to blow them so often, but they should be tried every week or two to see that they are clear, and if there is any oil or other foreign matter in them that should be blown out before they fill up and become useless. In this case the trap had never been blown since the plant was started.

Another time I got a hurry call from a 25-ton plant we had installed in a wholesale market in a small town. When I arrived on the job, the owner was about ready to throw the machine out of the place and the engineer was not in much better humor. They had not been able to use the machine for two days and had to get along as best they could by loading the cooler with ice, which was both expensive and troublesome.

The engineer informed me that the first sign of trouble was that the condenser pressure began to climb and it had risen from the usual 150 lb. to over 200 lb. This happened over a period of about a week. At the same time he had been compelled to keep on opening the expansion valves more and more until they were wide open, and still the suction pressure kept dropping down until it had fallen from 25 lb. to 10 in. vacuum. It was also impossible to get frost on the suction line, and even the frost on the expansion coils in the cooler thawed off.

I first thought that the system was entirely too short of ammonia, but there was a gage glass on the receiver and this was full. I even opened one of the joints in the liquid line about twenty feet from the liquid receiver just enough to let it dribble and found that there was plenty of both pressure and liquid in this part of the line. Next we went around the cooler, tried all the expansion valves and found them wide open with not the slightest sound of liquid passing through them. An expansion valve when it is working right and the plant is properly charged will sound something like a throttled water valve under high pressure. All the valves were frosted over, also the liquid line for about twenty feet back to where it was insulated. This was another good sign that something out of the ordinary was wrong, because the liquid line is never frosted if the plant is working right, and an expansion valve should have a sharp frost line across it where the pressure changes from the high to the low side. This will generally be diagonally across the body of the valve.

I thought at first that it might be due to the disk coming loose on the valve stem on a valve that had been installed the wrong way in the line, but there was no place where this could happen, there being only two valves in the line, one at the receiver and another in the cooler. However, the line was frosted far back of the valve in the cooler so that the trouble could not be in this valve. I had already tested the line ahead of the valve on the receiver when I opened the joint; therefore, the trouble could not be in either of these.

There was only one other possible reason for the trouble and that was that the liquid line was partly blocked by scale or other substance some place between the receiver and the expansion coils. Working on this theory, I began tracing the liquid line back to the basement where the compressor and receiver were located. Finally I came to a joint in the horizontal run of the line, where I heard a sizzling sound like an expansion valve that is just cracked off the seat. Removing the insulation, I found that the pipe was warm up to this flange while on the side going to the expansion coils it was frosted sharp, showing that the line was choked at this place until the pressure was throttled from the 200 lb. condenser pressure to that in the expansion coils, which was probably several inches vacuum.

We shut off the line at the expansion coils, and using the bypasses, we pumped out the receiver and the liquid line through one of the condenser coils, shutting off the other two stands. After the line was thoroughly pumped out, we broke open the joint and found that the steamfitter had failed to remove the burr made by the pipecutter in cutting the pipe. This reduced the inside diameter of the pipe over one-half and also provided an excellent pocket for scale and other matter to accumulate. This had piled up until it practically shut off the flow through the line. Of course, the liquid accumulated in the condenser and this increased the condenser pressure, while the amount of liquid getting through the blocked part of the pipe was not enough to keep the expansion coils working, and as a result the suction pressure dropped and the frost came off the expansion coils, the suction line, and the machine. After we had removed the scale and reamed out the pipe that made the trouble, everything went along fine.

Pumping Water with a Spiral-Spring Belt

What the eminent British scientists are pleased to call a "mechanical impertinence" has recently made its appearance in England, in the form of a unique pump which works by means of a spiral-spring belt, says the *Scientific American.*

The pump consists simply of a spiral-spring belt, a grooved weight which turns with the bottom loop of the belt and holds the latetr in place, and a driving crank and pulley for turning the belt. Despite this simple construction the pump is capable of lifting a thousand gallons of water per hour from a depth of 300 feet, even when worked only by hand, according to reports. The coil-like cable is sunk to any depth by a rotating weight. Obeying the law of capillary attraction, the water lodges between the turns of the spiral spring and only falls out when it reaches the top of the pump.

Testing Polyphase Watt-hour Meters

By P. B. Findley

Comparison is made between the single-phase and polyphase watt-hour meters. A detailed description is given of the meters, and how to test and adjust the polyphase type is explained.

SINCE the polyphase watt-hour meter consists of two single-phase elements mounted on a common shaft, its mechanical construction is practically the same as that of the single-phase instrument and the adjustments, except as noted in the following, are identical. In Fig. 1 is shown a Westinghouse type OA polyphase watt-hour meter with the cover removed, and Fig. 2 shows the back view of the meter element removed from the case.

The arrangement of the parts is indicated very clearly in the figures. An aluminum mounting frame *F* serves as a foundation for the meter element. To it are attached the iron punchings *M* and *M*, which form the magnetic circuits for both the upper and the lower metering elements. On the core are the current coils *C* and *C* and the potentials coils *P* and *P*. The permanent magnets *A* and *A* are fastened to L-shaped punchings, which in turn are secured to the frame by the clamping screws *S*. The adjustments for no load, light load and full load are made in precisely the same manner as for a single-phase meter, save that everything is in duplicate, as can be seen by comparing Figs. 1 and 2 with Figs. 3 and 4. The shaft has the same wire-type guide bearing at the top and ball-and-jewel bearing at the bottom, and the gear train to the register is on the same principle as that of the single-phase instrument. Those who have read the articles in the Jan. 28 and Feb. 4, 1919, issues of *Power*, on "Testing Single-Phase Watt-Hour Meters," will readily see that the polyphase meter described in this article is practically two single-phase meters similar to that described in the previous articles combined into one element. The single-phase meter is shown in Figs. 3 and 4, so that a convenient comparison can be made with Figs. 1 and 2 respectively.

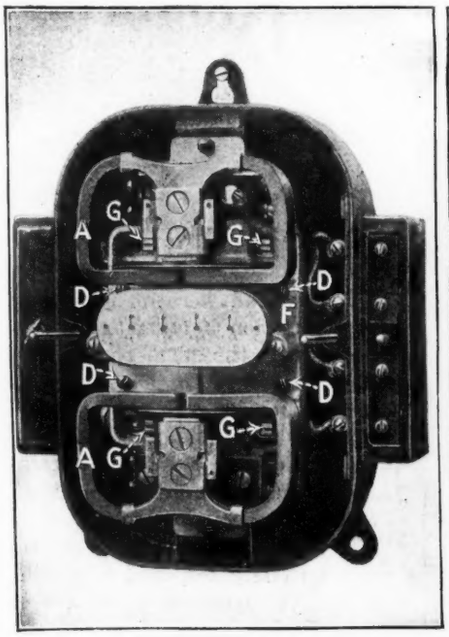


FIG. 1. POLYPHASE WATT-HOUR METER, COVER REMOVED

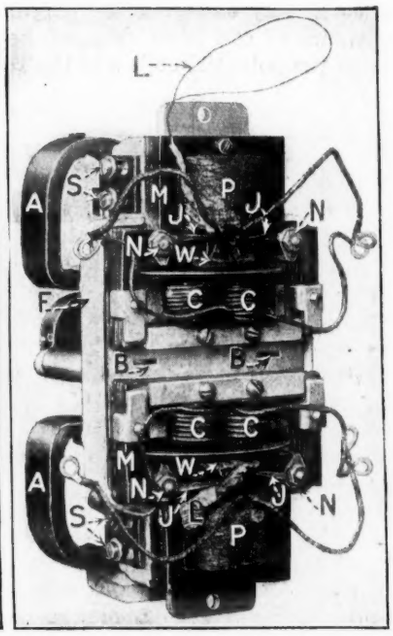


FIG. 2. REAR VIEW OF METERING ELEMENT, FIG. 1

The first test to be made on a polyphase watt-hour meter is at no-load. With operating voltage on both potential coils the light-load adjusting loops are moved by turning the square-headed screws *G* until the discs do not "creep" in either direction. About one-fourth of the adjustment should be made with each loop. Practically, this test is made by giving the discs a gentle push, first in one direction and then in the other, with the fingers; they should not continue to rotate in either direction. The light-load compensator in the meter under consideration consists of two metallic loops which pass through the air gaps in the potential coil's magnetic circuits. These can be seen at *J* Figs. 2 and 4, clamped under the hexagon nuts *N*. By turning with a screwdriver, the square-headed screws *G*, Figs 1 and 3, the loops can be made to move up and down in the air gaps.

The design of a polyphase meter is such that when properly adjusted the passage of one kilowatt-hour through either element will cause the registration of one kilowatt-hour on the dial. If one kilowatt-hour passes through each coil simultaneously, two kilowatt - hours will be registered. Therefore, each electromagnetic system, seen in the rear view, Fig. 2, must have the same effect on the rotating disc. Specifically, a current flowing through the upper current coils must have the same effect as if flowing through the lower coils. This adjustmeent, once made at the factory, is practically permanent indefinitely. For completeness, it is given here:

After the no-load adjustment is made, leaving the potential coils alive, connect the current coils in series and allow full-load current to flow, reversing one coil if necessary so that the discs do not rotate. If they do, remove the register mechanism, loosen the screws *D*, Fig. 1, and insert a screwdriver into the slots *B*, Fig. 2. The magnetic systems can be moved up and down as a unit with respect to the discs, and should be so placed that no rotation takes place. Then the effect of each current element will be the same on its respective disc. The current should be cut off, and the no-load adjustment checked and readjusted if need be. The clamping screws are tightened and the register replaced.

The next step is to adjust for light load. This is done in the same manner as for a single-phase meter, the connections being made as described later, so that operating voltage is applied to both potential coils, and about one-tenth full-load current flows through each current coil. A rotating-standard meter is included in the circuit, and the adjusting loops *J* are moved by the square-headed screws *G*, until the meter registers correctly.

Full load is next applied with the same connections as in the foregoing and the permanent magnets *A* adjusted for correct registration, the necessary movement being distributed among the four magnets.

Since the great majority of single-phase meters are used on lighting circuits which have high power-factor loads, they are adjusted for power-factor correction at the factory. Polyphase meters, however, generally serve such loads as induction motors, distribution circuits with partly loaded transformers, etc., the power-factor of which is low. They are therefore provided with lag adjustments, which are coils of copper wire *W*, Fig. 2, wound around the potential-coil pole tips and having long leads *L*. By changing the length of the leads *L* the resistance of coil *W* is changed, hence the magnetic flux from the potential coils and the rotation of the disc are also varied. This adjustment rarely requires attention, and it is not the general practice to check it except on new and repaired meters. The test is easily made, however; each phase should be tested separately with a wattmeter or one-half of a polyphase rotating-standard meter, with full-load current and voltage, the latter being lagged so as to give 0.50 to 0.70 power factor. Since a single-phase rotating standard is not specially adjusted for low power factors, it is not necessarily accurate enough for this test.

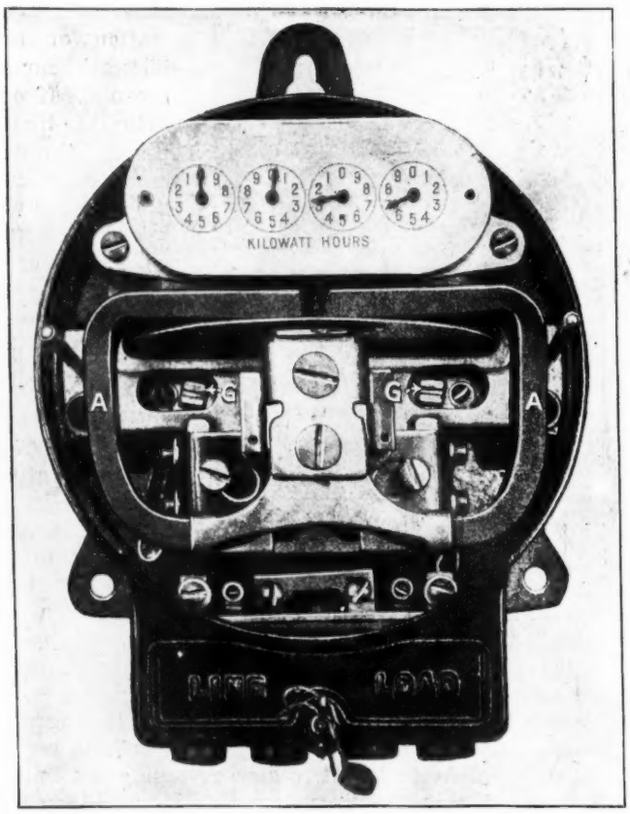


FIG. 3. SINGLE-PHASE WATT-HOUR METER

The essential constant of a watt-hour meter is the watt-hour constant, K_h, which is the watt-hours per revolution of the shaft. The constant for a polyphase meter is just double that for a single-phase meter of the same rating. A good way to visualize this is to remember that the polyphase meter consists of two single-phase elements of the same rating, locked together. If the same load were on each element, and we imagine the connection between them cut, they would continue to rotate at the same speed. Each would then rotate, let us say, once for each kilowatt-hour metered by it; that is, once for each two kilowatt-hours metered by the pair. Then if we locked them together, the combination would still continue to rotate once for each two kilowatt-hours metered; that is, K_h would be twice what it was for a single element.

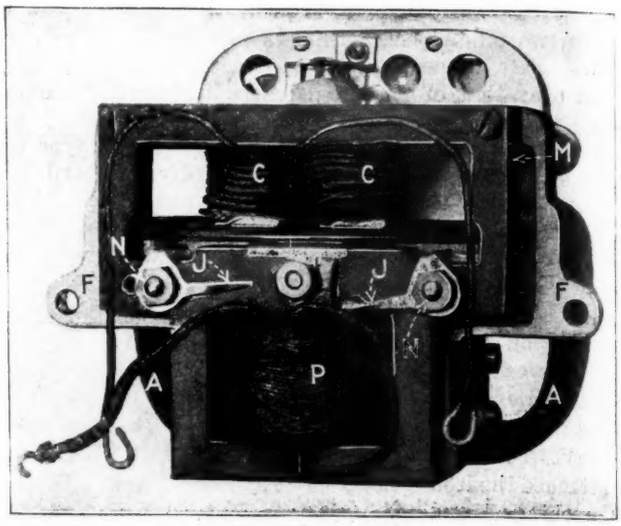


FIG. 4. REAR VIEW OF METERING ELEMENT, FIG. 3

In testing a polyphase meter ooth potential coils must be energized, and this will be assumed in what follows. Suppose, now, we are testing with both current coils in series and in turn connected in series with the current coil of a single-phase standard wattmeter. Then the power is registered twice by the service meter, once by the standard meter. So we must multiply the standard readings by 2 before using them in the formula,

$$E = \frac{3600\,K_h N \times 100}{PT} - 100$$

where

E = Per cent error, plus if service meter is fast and minus if service meter is slow;

K_h = Watt-hour constant of service meter;

N = Revolutions of service meter in T seconds and

P = Twice the true watts registered by the standard wattmeter.

If, however, we are testing with a single-phase rotating standard, in series with both current coils as above, then if K_h for the standard is half that for the service meter, we can compare revolutions directly. This can also be done if we have each element of the service meter connected to an element of a polyphase rotating

standard meter, where K_h for the standard is the same as for the service meter. Then

$$E = \frac{N \times 100}{M} - 100$$

where

E = Per cent error, plus if service meter is fast and minus if the service meter is slow;

N = Revolutions of service meter;

M = Revolutions of rotating standard.

This formula is true only under the conditions noted in the foregoing. If the polyphase rotating standard has a different watt-hour constant from the service meter, it is most convenient to use a conversion table furnished by the manufacturer of the standard meter, similar to that described in the article. "Testing Single-Phase Watt-Hour Meters With a Rotating Standard of Different Make," Oct. 28-Nov. 4, 1919, issue. For instance, suppose we have to test a Fort Wayne type K meter, 100 volts, 5 amperes, watt-hour constant 1,000, with a Westinghouse polyphase rotating standard set for 5 amperes 100 volts, having a watt-hour constant of 0.666. Setting the load on each phase to be approximately equal and to give 20 r.p.m. of the service meter, we find the number of revolutions of the standard which takes place in 20 revolutions of the service meter. Comparing this figure with the table, we find the percentage of error and adjust to eliminate it. If no table is at hand use the formula,

$$E = \frac{N_x K_{hx} \times 100}{N_s K_{hs}} - 100$$

where

E = Per cent error, plus if service meter is fast and minus if the service meter is slow;

N_x = Observed revolutions of service meter;

N_s = Observed revolutions of standard meter;

K_{hx} = Watt-hour constant of service meter;

K_{hs} = Watt-hour constant of standard polyphase meter.

The simplest way of testing a polyphase meter is to connect its potential coils in parallel across a suitable source of single-phase voltage, and its current coils in series with a single-phase rotating standard and a resistance load. Where a very large current is required and a suitable transformer is available, it may be used to supply current at low potential, the potential coils being energized from the line. For example, if a 200-ampere meter is to be tested, and a 25-kw. 2,200 to 110 to 220-volt transformer is available, the 2,200-volt coil could be connected to a 110-volt circuit and the two 110-volt coils connected in parallel, obtaining 5 volts with a capacity of 225 amperes. For the moderate currents usually required, as in testing meters to be used with current transformers, which are built for 100 volts and 5 amperes, the current is taken directly from a 110-volt line, as in Fig. 7. For high accuracy on low power factors, a polyphase rotating standard, Figs. 5 and 6, should be used. The connections for this test are given in Fig. 8. Obviously, power transformers for furnishing current at low voltage can be inserted in the current-supply wires. For testing at low power factors, a phase-shifting transformer should be inserted in the potential supply circuits. This is simply a small polyphase transformer whose secondary coils can be shifted to bring them partly under the influence of two primary coils instead of under one primary coil, as in the ordinary transformer. Thus the phase of the secondary voltage will lie between the phases of the two primary coils, and at any desired angle of lag or lead with the load current.

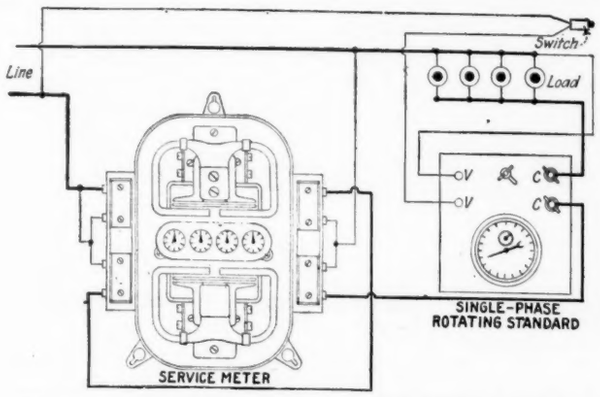


FIG. 7. TESTING POLYPHASE METER WITH SINGLE-PHASE ROTATING STANDARD

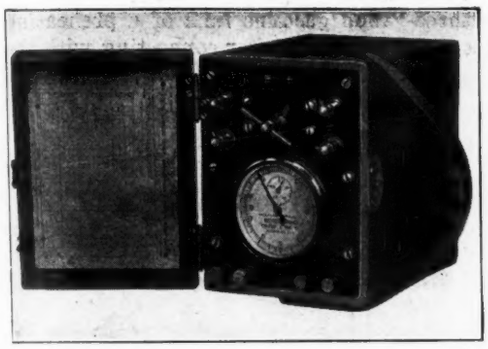


FIG. 5. POLYPHASE ROTATING STANDARD, EXTERIOR VIEW

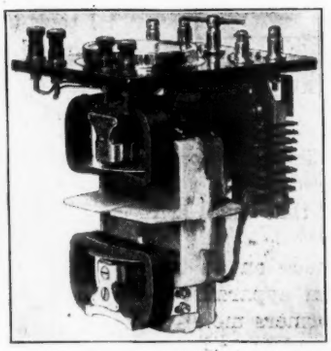


FIG. 6. INTERIOR VIEW METERING ELEMENT, FIG. 5.

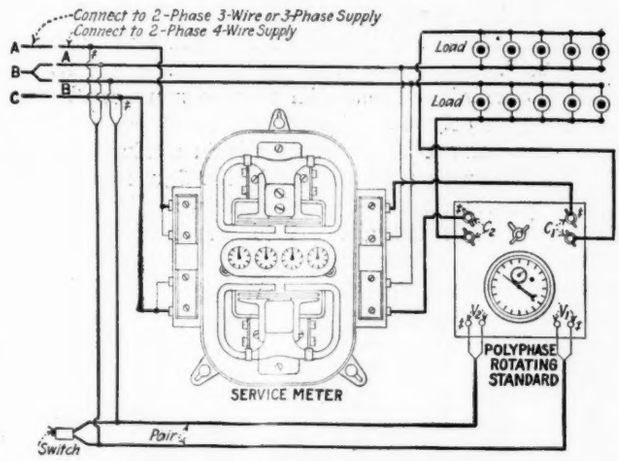


FIG. 8. TESTING POLYPHASE METER WITHOUT TRANSFORMERS WITH POLYPHASE ROTATING STANDARD

Wherever polyphase-meter connections are made, it is essential to have some check on the polarity of the various coils. Rotating standard meters have one volt-

age and one current terminal of each circuit marked, and these should be connected to the same wire of the supply circuit. A final check on the correctness is made as follows:

Place a small noninductive (resistance) load on each phase. Open the potential circuit of the upper element, and the current circuit of the lower element (first short-circuiting the current transformer winding if transformers are used). If the meter runs at all, the potential circuits have been transposed between the line and

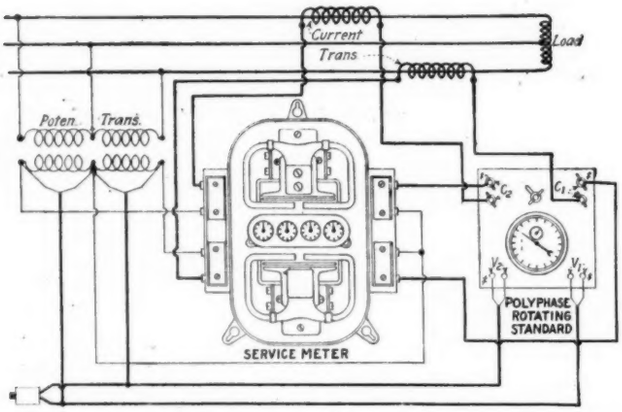


FIG. 9. TESTING POLYPHASE METER WITH TRANSFORMERS WITH ROTATING STANDARD

the meter. Interchange the potential circuits—upper for lower—and test again. If the meter does not run, the proper phases are together, assuming that there are no "shorts" or "opens" in the wiring.

Occasionally, these checks must be made on an installation which serves only high-tension apparatus—for instance, 2,200-volt motors or transformers metered on the "high" side. Here an artificial load is impracticable. The test should be made therefore with the apparatus loaded, since at light loads both transformers and induction motors have low power factors. When the power factor of a polyphase circuit is below 0.50, one element of a watt-hour meter will try to run backward so that rotation backward would mean nothing unless we were sure that the power factor was above 0.50. On the average for loads of above 15 per cent of full load, the power factor of an induction motor is above 0.50.

Both current and potential transformers are generally used on polyphase circuits, either for safety or to bring the current in the meter within workable limits, Fig. 9. The meter connections in the figure are of the simplest sort; its two current and two potential coils have both ends brought out to its terminal boards, whence they are connected to the transformers. While some complicated wiring schemes may be found, especially if relays or other meters are served from the same transformers, yet they are in general simple. The following points should be borne in mind when dealing with any such installation:

1. A current transformer will be ruined if the secondary is opened while the primary is carrying current. Therefore, always keep the secondary closed, either through some instrument current coil, or through a short-circuit.

2. Most instrument potential transformers are rated at 25 watts. Never overload them.

3. If not abused, instrument transformers will retain their accuracy for at least five years. Therefore, routine tests of instruments may be made on the low-voltage side of the transformers.

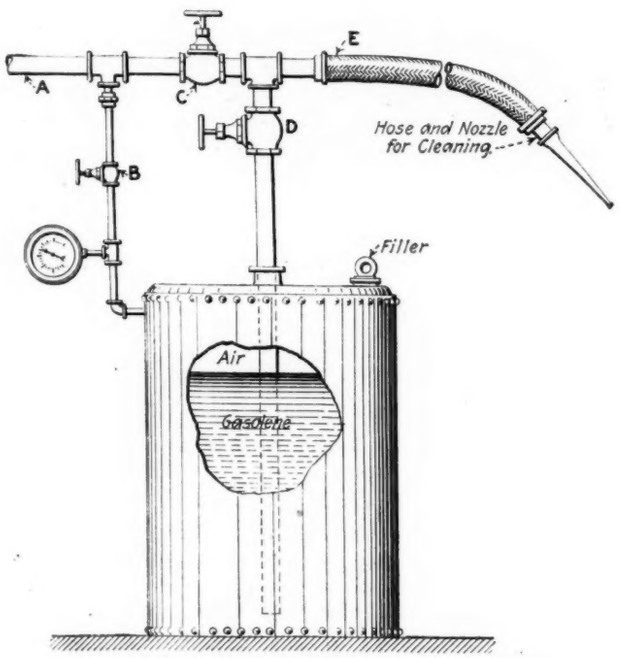
4. In thus testing a polyphase watt-hour meter with a polyphase standard on a running load, simply insert one current coil of the standard in each current lead at the meter, and connect the potential coil of the standard across the proper potential terminals of the service meter as in Fig. 9, and make sure that each rotating standard element drives the discs forward.

Cleaning Apparatus for Generator Windings

BY F. C. WILLIAMS

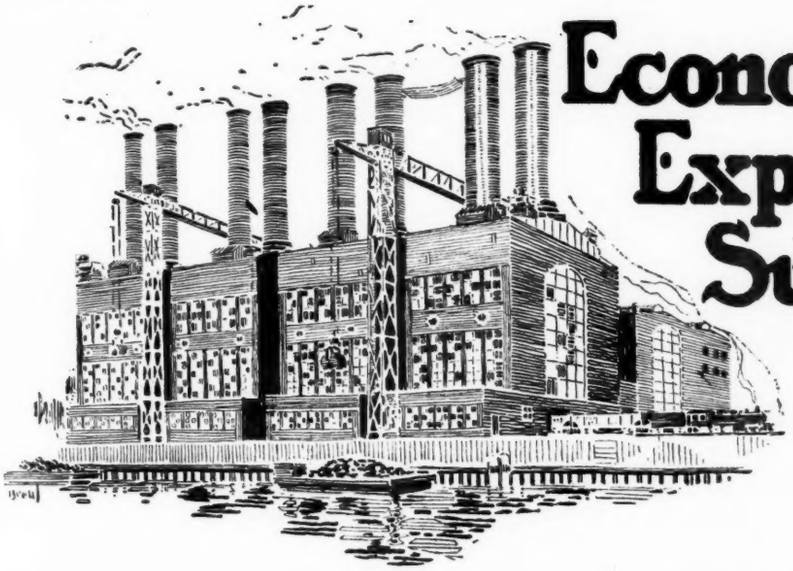
The sketch shows an apparatus that I rigged up for cleaning the windings of generators and motors. It was made from material that was found around the plant. We have high winds and much dust, and it is a problem to keep the machinery clean. We have four oil and gas engines, each with its own air-starting tank, but all are piped together and so the supply of compressed air is sufficient.

I took the three-gallon gasoline tank of a preheating torch and piped it as shown. After connecting with the air supply at *A*, with all valves closed, the pressure was



AIR AND GASOLINE APPARATUS FOR CLEANING GENERATOR WINDINGS

turned on and then the globe valve *B* on the air line was cracked and a pressure built up in the gasoline tank to about twenty or thirty pounds. This valve was then closed and the valve *C*, between the two tees at the top, opened to give the proper blast. Then the valve *D* on the gasoline line was cracked. The result was a spray of air and gasoline through the nozzle, which has about a $\frac{1}{16}$-in. opening. This spray reaches into cracks and holes where nothing else can go and brings out the dirt and grease.



Economies to be Expected of Superstation*

by

John A. Stevens†

Deals with the economies to be expected of superstations, including heat balance, power costs at the switchboard, latest forms of byproduct steam turbines for producing heating and manufacturing steam and the economies that are obtained by using them, and suggestions regarding the placing of super-power stations in large industrial communities.

IN PRESENTING this article, it seems best to carry the reader through the various power-development stages from approximately the first generation of electricity by means of the simple non-condensing engine to the latest development in power-plant machinery design. Table I shows the advance in the art of steam engineering, with special reference to engines, dating from the small high-speed slide-valve engines to the 5,000-kw. angle compound engines (7,500 hp. maximum) of the Interborough Rapid Transit Co., which represent about the height of the development in so far as reciprocating steam engines go. These engines, although more efficient after thirteen years of service than when first installed, were supplanted in 1917 by cross-compound reaction turbines of 30,000-kw. capacity.

Table II shows the evolution of steam-turbine practice, starting with a very small steam exciter set of 35-kw. capacity, exhausting to the atmosphere, and carrying the development through to the 50,000-kw. units of the three-cylinder type, having a maximum rating of 70,000 kw. The specific types of turbines referred to in this article, however, are the 30,000-kw. units, which show a thermal efficiency of 26.5 per cent.

The economies shown by Table II graphically bring out the reasons why engineers are working toward the great super-station, the necessity for which is illustrated by Fig. 1, which shows the growth of central-station operations[1]. Behind the growth of the central station is the fact that building super-stations is, economically speaking, the right thing to do.

Power stations that are built from now on should be of the so-called super-power-station design, and although the supplement design accompanying the May 25 issue of *Power* may not be adopted, it may suggest to other engineers a better design than has thus far been used, especially with reference to the handling of the condensing water, coal into the station, ashes away from the station, and the minimum number of men employed per kilowatt output, as well as the minimum cost of construction.

Regarding the economies of this type of station, the heat-balance sheets, Fig. 2, illustrate the possibilities, provided the exact conditions stated on the sheets are carried out, such as steam pressure, superheat or total temperature, vacuum or exhaust pressures, and also the correct and proper heat balances maintained at all times in the station.

Two heat-balance sheets for the stated efficiency of the boiler are shown. The higher economies shown by the second sheet are with steam extracted from the upper stages of the turbine and used in preheating the combustion air to a moderate temperature, say 170 deg. The preheating of combustion air has been tried out and used many times, but a moderate degree of preheating the air has, to the writer's knowledge, never been scientifically arranged for, installed and used, other than with the Howden's forced-draft system or Ellis & Eaves' systems in marine work, which have been notably successful.

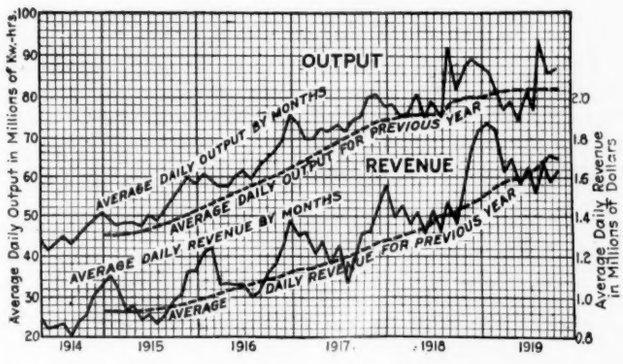


FIG. 1. SHOWING GROWTH OF CENTRAL-STATION OPERATION

*Illustrated in the May 25, 1920 issue of *Power*.

†Consulting Engineer, Lowell, Mass.

[1]From McGraw-Hill Co.'s brochure, March, 1920.

Regarding the boiler efficiency given, the company handling these boilers authorized the statement that it will guarantee an efficiency of 85 per cent and that a higher efficiency may be expected. An eminent engineer has also stated that 87½ or even 90 per cent over-all efficiency might be obtained with the system of double jacketing the boilers and circulating the heat of radiation, as well as the cooling air from the generator, into and through the furnaces; especially so if either oil or pulverized coal is used as a fuel. At least, the economies shown work out in this way mathematically, and it appears that if great care and skill are used in the design, the efficiencies recorded may be obtained at the outgoing leads of the station.

The heat-balance diagrams are worked out to scale, and the use of steam in the auxiliaries and the radiation of buildings is in direct proportion to the balance of the diagram. It is hoped that some engineer will discover a way in the future to reduce the condenser circulating-water losses. Some attempts have already been made to do this, but as yet they do not appear to be successful in practice.

The sizes of the units, boilers, turbines and switch gear are limited only by the unit size of the boilers, and the first sheet of Fig. 2 shows the possibilities of the super-station when Stevens-Pratt boilers are used. To illustrate further the economies of such a station, Table III shows the power costs at the switchboard of a 100,000-kw. steam-turbine station. Attention is called to the coal cost in mills per kilowatt-hour with different load factors. Fig. 3 is a graphic curve illustrating still further the possibilities of a super-station. These figures may not be exactly correct, but it is the system of working out rather than the results which are illustrated, principally for the use of the engineering generation that has not had to do with matters that relate to super-power stations.

TABLE I. SHOWING THE ADVANCE IN ENGINE ECONOMIES

Size and Type of Unit	Steam Conditions: Initial Pressure, Lb. Gage and Deg. Superheat	Steam Conditions: Final Pressure, In. Mercury	Perfect Engine (Rankine Cycle): B.t.u. Kw., per Min.	Perfect Engine (Rankine Cycle): Rankine Eff.	Actual Engine: Steam Rate, Lb. per Kw.-Hr.	Actual Engine: B.t.u. Kw. per Min.	Actual Engine: Thermal Eff. per Cent	Actual Engine: Ratio per Cent Thermal Eff. Rankine Eff.
50-kw. high-speed slide-valve engine	100 dry	Atmos.	386.0	14.75	48.0	807	7.05	47.8
1,000-kw. cross-compound Corliss	150 dry	26.0	216.5	26.3	21.0	386	14.75	56.0
3,750-kw. N. Y. Edison engines	185 dry	27.0	202.5	28.1	16.8	312	18.25	65.0
5,000-kw. Interborough engines	175 dry	25.5	214.5	26.5	17.1	314	18.10	68.4

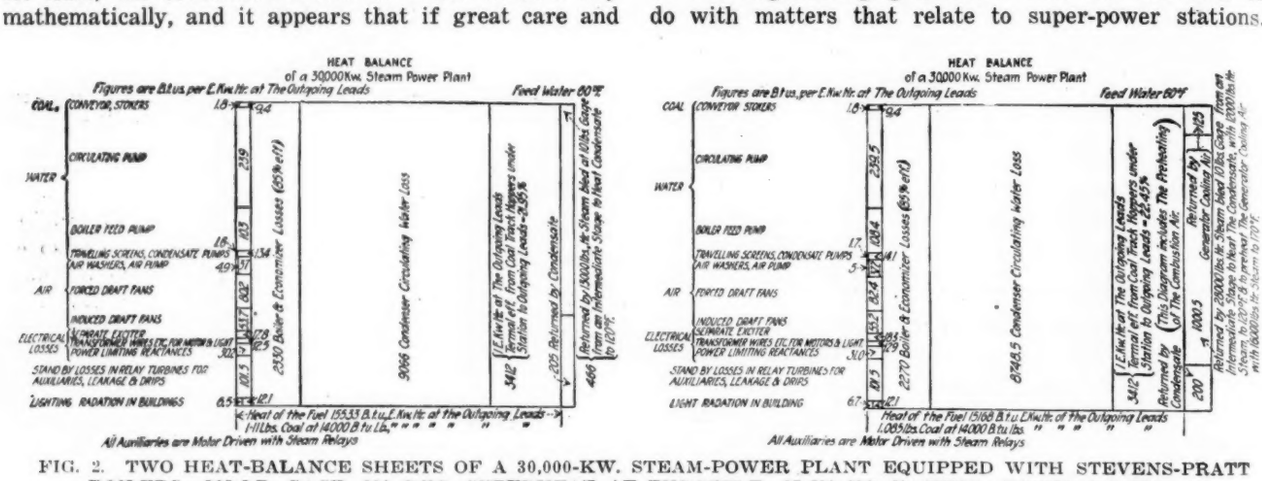

HEAT BALANCE
of a 30000Kw. Steam Power Plant
Figures are B.t.u. per E.Kw.Hr. at The Outgoing Leads
Feed Water 60°F
COAL
CONVEYOR, STOKERS
CIRCULATING PUMP
WATER
BOILER FEED PUMP
TRAVELING SCREENS, CONDENSATE PUMPS
AIR WASHERS, AIR PUMP
AIR
FORCED DRAFT FANS
INDUCED DRAFT FANS
ELECTRICAL LOSSES
EXCITER
TRANSFORMER WIRES ETC. FOR MOTORS & LIGHT
POWER LIMITING REACTANCES
STAND BY LOSSES IN RELAY TURBINES FOR AUXILIARIES, LEAKAGE & DRIPS
LIGHTING RADIATION IN BUILDINGS
2350 Boiler & Economizer Losses (65% eff.)
9066 Condenser Circulating Water Loss
205 Returned by Condensate
466
Heat of the Fuel 15533 B.t.u. E.Kw.Hr. at The Outgoing Leads
All Auxiliaries are Motor Driven with Steam Relays
HEAT BALANCE
of a 30000 Kw. Steam Power Plant
Figures are B.t.u. per E.Kw.Hr. at The Outgoing Leads
Feed Water 60°F
COAL
CONVEYOR STOKERS
CIRCULATING PUMP
WATER
BOILER FEED PUMP
TRAVELLING SCREENS, CONDENSATE PUMPS
AIR WASHERS, AIR PUMP
AIR
FORCED DRAFT FANS
INDUCED DRAFT FANS
ELECTRICAL LOSSES
EXCITER
TRANSFORMER WIRES ETC. FOR MOTORS & LIGHT
POWER LIMITING REACTANCES
STAND BY LOSSES IN RELAY TURBINES FOR AUXILIARIES, LEAKAGE & DRIPS
LIGHT RADIATION IN BUILDING
2270 Boiler & Economizer Losses (65% eff.)
8746.5 Condenser Circulating Water Loss
Heat of the Fuel 15168 B.t.u. E.Kw.Hr. at The Outgoing Leads
All Auxiliaries are Motor Driven with Steam Relays

FIG. 2. TWO HEAT-BALANCE SHEETS OF A 30,000-KW. STEAM-POWER PLANT EQUIPPED WITH STEVENS-PRATT BOILERS; 325-LB. GAGE, 200 DEG. SUPERHEAT AT THROTTLE; 27 IN. HG. VACUUM; POWER FACTOR, 0.8; EFFICIENCY, RANKINE CYCLE, 76 PER CENT

In addition to the power generated by super-stations in the central-power service of the future, there is another element of conservation that may be made. While up to the present time district heating with systems as an auxiliary to central-power stations has not been much thought of or developed in America, and while some attempted systems have not been successful financially because of lack of proper foresight and experience, the possibility of thus making use of heat energy that otherwise would largely go to waste in the form of condensing-water discharge must make this form of service of increasing interest and importance. In most all industries (other than very large

TABLE II. SHOWING THE EVOLUTION OF TURBINE PRACTICE

Size and Type of Unit	Steam Condition: Initial Pressure, Lb. Gage and Deg. Superheat	Steam Condition: Final Pressure, In. Mercury	Perfect Engine (Rankine Cycle): B.t.u. Kw., per Min.	Perfect Engine (Rankine Cycle): Rankine Eff.	Actual Engine: Steam Rate, Lb. per Kw.-Hr.	Actual Engine: B.t.u. Kw. per Min.	Actual Engine: Thermal Eff. per Cent	Actual Engine: Ratio per Cent. Thermal Eff. Rankine Eff.
35-kw. steam-turbine exciter set	175–100	Atmos.	309.0	18.4	47.0	844	6.74	36.7
100-kw. horizontal turbine	150-dry	28.0	197.0	28.9	25.0	469	12.12	42.0
500-kw. vertical turbine	150-dry	28.0	197.0	28.9	24.0	450	12.63	43.8
500-kw. horizontal turbine	150-dry	28.0	197.0	28.9	19.5	365	15.58	54.0
500-kw. horizontal turbine	175-100	28.0	190.0	29.5	17.1	338	16.85	56.3
1000 kw. horizontal turbine (multi-velocity stage)	150-100	28.5	190.5	29.9	14.3	285	19.3	66.7
20,000-kw. turbine	190-100	28.5	184.0	31.0	13.8	276	20.6	66.7
30,000-kw. -50,000-kw. turbine	265-250	29.0	164.5	34.6	10.6	229	24.8	72.0
*50,000-kw. turbine, three-cylinder unit	250-250	29.0	165.0	34.5	9.95	215	26.5	76.8
	300-200	28.5	169.0	33.7	10.2	214	26.5	78.8

* Maximum rating, 70,000 kw.

machine shops and similar processes) large volumes of manufacturing and heating steam are used. Several instances are known of factories using 300,000 to 400,000 lb. of steam an hour for heating and manufacturing processes, and in the power arrangement of the near future the electric energy used for power will be generated in super-steam stations, from hydro-electric plants, or both, as well as the manufacturing steam made as a byproduct to power. There is nothing new in this principle, since we have records in New England manufacturing plants of this system being used as early as 1860, when a very able naval engineer was employed by a large textile mill to change over its steam system. He arranged to use non-condensing engines at 10 or 12 lb. back pressure for the producing of approximately 100,000 to 150,000 lb. of steam an hour for the dyehouse, bleachery and steam heating of the plant.

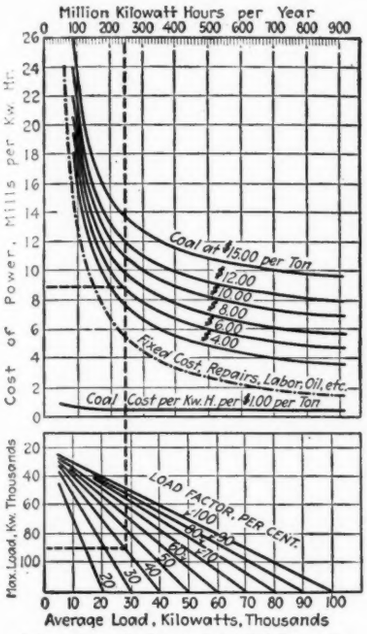


FIG. 3. COST OF POWER OF 100,000-KW. STEAM PLANT AT TIDEWATER

As early as 1907 the writer investigated the use of turbines in this manner and from that day to this has installed a great many machines, some running entirely non-condensing and some with different arrangements of stage extraction or admission of steam to the lower stages of the turbines as the case might be; that is to say, connected to a common low-pressure or exhaust main with steam engines and pumps operating non-condensing so that at off-peak periods, the exhaust of the non-condensing engines could be

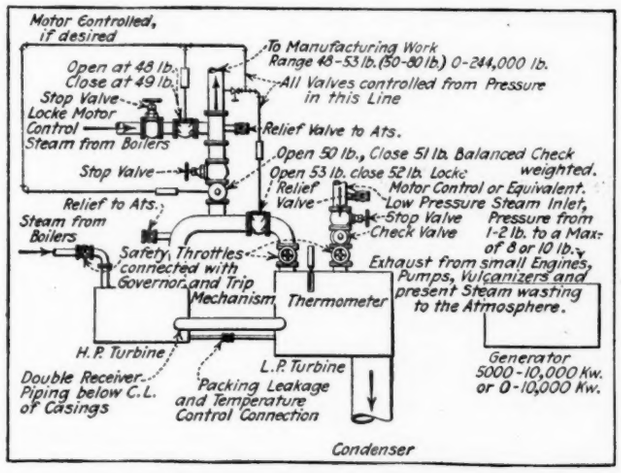

Motor Controlled, if desired
To Manufacturing Work
Range 48-53 lb. (50-80 lb.) 0-244,000 lb.
Open at 48 lb.
Close at 49 lb.
All Valves controlled from Pressure in this Line
Stop Valve
Locke Motor Control
Steam from Boilers
Relief Valve to Ats.
Open 50 lb., Close 51 lb. Balanced Check
Stop Valve
Open 53 lb. close 52 lb. Locke Relief Valve
weighted.
Motor Control or Equivalent.
Low Pressure Steam Inlet, Pressure from 1-2 lb. to a Max- of 8 or 10 lb.
Relief to Ats.
Steam from Boilers
Stop Valve
Check Valve
Safety Throttles connected with Governor and Trip Mechanism
Thermometer
Exhaust from small Engines, Pumps, Vulcanizers and present Steam wasting to the Atmosphere.
H.P. Turbine
L.P. Turbine
Generator 5000-10,000 Kw. or 0-10,000 Kw.
Double Receiver Piping below C.L. of Casings
Packing Leakage and Temperature Control Connection
Condenser

FIG. 4. DIAGRAMMATIC SKETCH OF DOUBLE-CYLINDER EXTRACTION AND LOW-PRESSURE TURBINE

TABLE III. POWER COSTS AT SWITCHBOARD OF 100,000-KW. STEAM-TURBINE STATION

Main Units—4—35,000-kw. turbines—economy—10 lb. steam per kw.-hr.; 4—5,800-Hp. B.&W., Stevens-Pratt boilers and economizers 85 per cent over-all efficiency. Investment—$10,000,000

Maximum Load in Kw.	Load Factor, per Cent.*	Average Load, in Kw.	Kw.-Hr. per Year	Fixed Cost, Labor, Repairs, Etc., Mills per Kw.-Hr.	Coal, Cost, Mills per Kw.-Hr.	Total Cost of Power—Mills per Kw.-Hr. Coal per Ton at $4.00	$6.00	$8.00	$10.00	$12.00	$15.00
100,000	100	100,000	876,000,000	1.56	†0.55	3.76	4.86	5.96	7.06	8.16	9.81
	90	90,000	788,400,000	1.74	0.55	3.94	5.04	6.14	7.24	8.34	9.99
	80	80,000	700,800,000	1.95	0.55	4.15	5.25	6.35	7.45	8.55	10.20
	70	70,000	613,200,000	2.23	0.55	4.43	5.53	6.63	7.73	8.83	10.48
	60	60,000	525,600,000	2.61	0.55	4.81	5.91	7.01	8.11	9.21	10.86
	50	50,000	438,000,000	3.13	0.55	5.33	6.43	7.53	8.63	9.73	11.38
	40	40,000	350,400,000	3.91	0.55	6.11	7.21	8.31	9.41	10.51	12.16
	30	30,000	262,800,000	5.21	0.55	7.41	8.51	9.61	10.71	11.81	13.46
	20	20,000	175,200,000	7.81	0.55	10.01	11.11	12.21	13.31	14.41	16.06
80,000	100	80,000	700,800,000	1.95	0.55	4.15	5.25	6.35	7.45	8.55	10.20
	90	72,000	630,720,000	2.17	0.55	4.37	5.47	6.57	7.67	8.77	10.42
	80	64,000	560,640,000	2.44	0.55	4.64	5.74	6.84	7.94	9.04	10.69
	70	56,000	490,560,000	2.79	0.55	4.99	6.09	7.19	8.29	9.39	11.04
	60	48,000	420,480,000	3.26	0.55	5.46	6.56	7.66	8.76	9.86	11.51
	50	40,000	350,400,000	3.91	0.55	6.11	7.21	8.21	9.31	10.41	12.06
	40	32,000	280,320,000	4.89	0.55	7.09	8.19	9.29	10.39	11.49	13.14
	30	24,000	210,240,000	6.51	0.55	8.71	9.81	10.91	12.01	13.11	14.76
	20	16,000	140,160,000	9.78	0.59	12.14	13.32	14.50	15.68	16.86	18.63
60,000	100	60,000	525,600,000	2.61	0.55	4.81	5.91	7.01	8.11	9.21	10.86
	90	54,000	473,040,000	2.90	0.55	5.10	6.20	7.30	8.40	9.50	11.15
	80	48,000	420,480,000	3.26	0.55	5.46	6.56	7.66	8.76	9.86	11.51
	70	42,000	368,920,000	3.73	0.55	5.93	7.03	8.13	9.23	10.23	11.88
	60	36,000	315,360,000	4.35	0.55	6.55	7.65	8.75	9.85	10.95	12.60
	50	30,000	262,800,000	5.21	0.55	7.41	8.51	9.61	10.71	11.81	13.46
	40	24,000	210,240,000	6.51	0.55	8.71	9.81	10.91	12.01	13.11	14.76
	30	18,000	157,680,000	8.69	0.57	10.97	12.17	13.25	14.39	15.53	17.24
	20	12,000	105,120,000	13.02	0.68	15.74	17.10	18.46	19.82	21.18	23.22
40,000	100	40,000	350,400,000	3.91	0.55	6.11	7.21	8.31	9.41	10.51	12.16
	90	36,000	315,360,000	4.35	0.55	6.55	7.65	8.75	9.85	10.95	12.60
	80	32,000	280,320,000	4.89	0.55	7.09	8.19	9.29	10.39	11.49	13.14
	70	28,000	245,280,000	5.58	0.55	7.78	8.88	9.98	11.08	12.18	13.73
	60	24,000	214,240,000	6.51	0.55	8.71	9.81	10.91	12.01	13.11	14.76
	50	20,000	175,200,000	7.81	0.55	10.01	11.11	12.21	13.31	14.41	16.06
	40	16,000	140,160,000	9.78	0.59	12.14	13.32	14.50	15.68	16.86	18.63
	30	12,000	105,120,000	13.02	0.68	15.74	17.10	18.46	19.92	21.18	23.22
20,000	100	20,000	175,200,000	7.81	0.55	10.01	11.11	12.21	13.31	14.41	16.06
	90	18,000	157,680,000	8.69	0.57	10.97	12.17	13.25	14.39	15.53	17.24
	80	16,000	140,160,000	9.78	0.59	12.14	13.32	14.50	15.68	16.86	18.63
	70	14,000	122,640,000	11.16	0.61	13.60	14.82	16.04	17.26	18.48	20.31
	60	12,000	107,120,000	13.02	0.68	15.74	17.10	18.46	19.82	21.18	23.22
	50	10,000	87,600,000	15.62	0.71	18.46	19.88	21.30	22.72	24.14	26.27

* Load factor taken as ratio of average load to maximum coal consumption is figured with 15 per cent leeway above guarantees.
† Coal cost per kw.-hr. per $1 per ton.

used in the lower stages of the turbine rather than wasting it, since in textile mills there is a large waste of steam, due to the fact that the dyehouse load usually goes off from 11:30 to 12 in the morning and again at 4 in the afternoon.

Until quite recently no turbines were built for operating non-condensing or against a back pressure of over

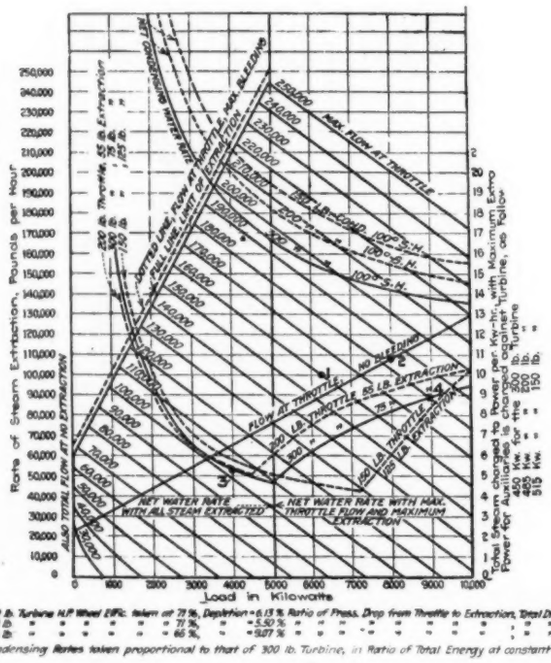

Rate of Steam Extraction, Pounds per Hour
Load in Kilowatts
Total Steam charged to Power per Kw.-hr., with Maximum Extraction, as Follows
Power for Auxiliaries is charged against Turbine, as follows
450 Kw. for the 300 lb. Turbine
415 Kw. " " 200 lb. " "
375 Kw. " " 150 lb. " "
NET CONDENSING WATER RATE
BOTTLED LINE—FLOW AT THROTTLE, MAX. BLEEDING
FULL LINE—LIMIT OF EXTRACTION
ALSO TOTAL FLOW AT NO EXTRACTION
MAX. FLOW AT THROTTLE
300 LB.—COND. 100° F. S. H.
200 " " 100° " "
150 " " 100° " "
NO BLEEDING
FLOW AT THROTTLE
300 LB. THROTTLE 85 LB. EXTRACTION
200 LB. THROTTLE 85 LB. EXTRACTION
150 LB. THROTTLE 85 LB. EXTRACTION
NET WATER RATE WITH ALL STEAM EXTRACTED
NET WATER RATE WITH MAX. THROTTLE FLOW AND MAXIMUM EXTRACTION
300 lb. Turbine H.P. Wheel Eff'c. taken at 71 %, Depletion = 6.13 %, Ratio of Press. Drop from Throttle to Extraction, Total Drop = 73 %
200 lb. " " " " " 71 % " = 5.50 % " " " " " " " " " = 66 %
150 lb. " " " " " 66 % " = 5.07 % " " " " " " " " " = 63.5 %
Condensing Rates taken proportional to that of 300 lb. Turbine, in Ratio of Total Energy at constant Entropy

FIG. 5. ECONOMIES OF A 10,000-KW. DOUBLE-CYLINDER EXTRACTION AND LOW-PRESSURE STEAM TURBINE: 300-LB. GAGE, 100 DEG. F.; 2-IN. ABS. 75-LB. GAGE STEAM EXTRACTION

No. 1—Curves shown dotted are for other turbines than 10,000-kw. plotted to same scale of extraction, kilowatts and steam charged to power per kilowatt-hour, but with different steam-flow curves, not shown. No. 2—Maximum throttle flow taken at 250,000-lb. for all turbines. No. 3—Generator and friction losses taken at 10.4 per cent for all turbines. No. 4—Extraction water apply only when all possible steam is being extracted.

60 lb., but in the rubber industry 80 to 90 lb., or even 100 lb., is desired, and to cope with this condition a turbine arrangement as shown in Fig. 4 was evolved.

This machine is termed a double-cylinder extraction and low-pressure turbine. It consists of a high-pressure and a low-pressure turbine mounted on one shaft with, say, a 10,000-kw. generator. This machine will operate automatically with steam extracted from 0 gage to, say, 80 lb. pressure and from 0 to 244,000 lb. extracted at a predetermined pressure. It will operate entirely condensing with only a slightly reduced economy from that of a standard machine, and it will operate also for any intermediate extraction of steam or generation of power. At the same time large amounts of steam may be admitted to the low-pressure casings in the way of returns from vulcanizing machinery, which should be put through regenerators or separators at 1 to 2 lb. pressure for the precipitation of the acids. The control of this machine is from the sustained or maintained pressure in the steam line to the manufacturing systems. In other words, the machine is controlled from its by-product rather than from its electrical end; but at the same time, if more service is demanded from the electrical end than the proportionate amount of steam passing through to the manufacturing process would admit, the automatic valve mechanism will open to the low-pressure or condensing turbine the necessary amount of steam to follow the electrical demands.

The economies of this machine are illustrated by Fig. 5, and it will be observed what splendid economies are obtained from a machine of this type, which may be installed to keep the entire output of the machine when running non-condensing or part non-condensing and part condensing, at a rate of 7 lb. of steam or even less per kilowatt-hour at the generator leads chargeable to power in kilowatts.

At the left of the center line in each sheet are shown the amounts of steam chargeable per kilowatt-hour when operating non-condensing, and to the right of the dip of each curve, the effect of some or part of the steam passing on to the condenser. These curves include a liberal allowance for the amount of steam or power used by a jet condenser and therefore give the total approximate amount of steam chargeable to power as generated by this byproduct machine. If a surface-condensing equipment were used, these would be substantially cut, which would still further reduce the amount of steam chargeable per kilowatt-hour produced.

Patents are now pending which will protect the company that evolved this turbine in connection with the writer and his staff.

For a more simple illustration of the great possibilities of non-condensing turbines to match or phase

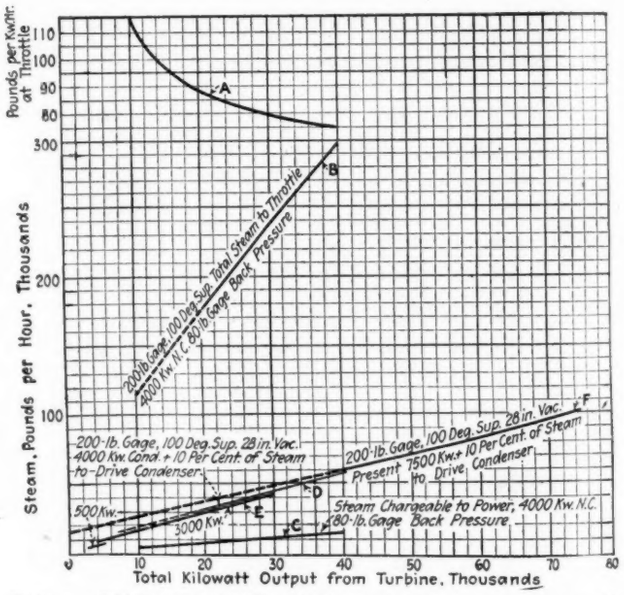

Pounds per Kw.hr. at Throttle
Steam, Pounds per Hour, Thousands
Total Kilowatt Output from Turbine, Thousands
A
B
200 lb. Gage, 100 Deg. Sup. Total Steam to Throttle
4000 Kw. N.C. 80 lb Gage Back Pressure
200-lb. Gage, 100 Deg. Sup. 28 in. Vac.
4000 Kw. Cond. + 10 Per Cent. of Steam to Drive Condenser
200-lb. Gage, 100 Deg. Sup. 28 in. Vac.
Present 7500 Kw. + 10 Per Cent. of Steam to Drive Condenser
500 Kw.
3000 Kw.
Steam Chargeable to Power, 4000 Kw. N.C. 80-lb. Gage Back Pressure
C
D
E
F
G

FIG. 6. COMPARISON OF TOTAL STEAM CHARGEABLE TO POWER FROM CONDENSING AND NON-CONDENSING TURBINES UNDER CONDITIONS AS STATED FOR THE SEVERAL CURVES

Curve *A*, estimated total steam per kilowatt-hour, 4,000-kw. turbine. *B*, estimated total throttle steam, 4,000-kw. turbine. *C*, estimated total steam chargeable to power, 4,000-kw. turbine. *D*, estimated total, throttle steam for 4,000-kw. turbine plus 10 per cent of steam for condensers. *E* and *F*, 3,000- and 7,500-kw. turbine, same conditions. *G*, total throttle steam for 500-kw. turbine.

in with the super-station or central station, owned by a public utility or owned and operated by the plant in question, see Figs. 6 and 7.

This type of turbine is in effect a "power-producing pressure-reducing turbine" and can be constructed in practically any size up to 2,500-kw. capacity and is so valved and arranged that it will automatically float

on the line and deliver quantities of steam in proportion to the demand, giving a proportionate amount of byproduct power; in other words, it is similar to a reducing valve, and the splendid economies of this turbine in one particular instance are illustrated by Figs. 6 and 7.

As these turbines are manufactured in small units, they may be located at a distance from the boiler

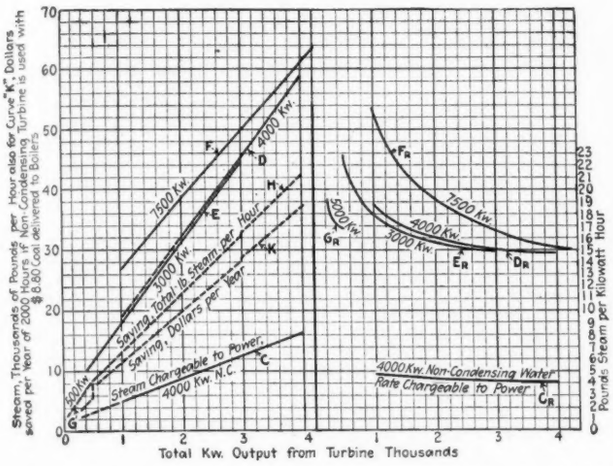


FIG. 7. COMPARISON OF TOTAL STEAM CHARGEABLE TO POWER FROM CONDENSING AND NON-CONDENSING TURBINES UNDER CONDITIONS STATED FOR THE SEVERAL CURVES

Curve *C*, estimated total steam chargeable to power, 4,000-kw. turbine, 200-lb. gage, 100-deg. superheat 80-lb. gage exhaust. *D*, estimated total steam for 4,000-kw. turbine. *E*, 3,000-kw. turbine. *F*, 7,500-kw. turbine. *G*, 500-kw. turbine. All with 200-lb. steam, 100-deg. superheat, 28-in. vacuum. *H*, difference in total pound steam per hour between curve *C* and curve *D*, *F* or *G*, whichever is lowest. *K*, dollars gross saving per year of 2,000 hours' operation at kilowatt rate, 9-lb. evaporation and coal at $8.80 in bunker if non-condensing turbine is used. *Cr*, *Dr*, *Er*, *Fr* and *Gr*, kilowatt-hour rate curves corresponding to total steam curves *C*, *D*, *E*, *F* and *G*.

plant; that is, used locally for outlying buildings, or at or near the processes using large amounts of steam, which will do away with the necessity of running large and very expensive low-pressure mains, throughout the plant from the central station. They should, however, be connected into the main electrical distribution systems. This turbine is evolved and standardized by one of the large electric companies, and therefore is a marketable commercial product at the present time. A diagrammatic sketch of such a unit is shown in Fig. 8.

To sum up, the power plant of the future will be along the basic lines suggested by this article, and it is suggested that power contracts be made with the permission to manufacture what power is desired by byproduct turbines—that is, byproduct to power production—and by such station designs as was shown in the May 25 issue of *Power* and in this article, as giving a complete program which should be followed.

In the actual working out of designs for multiple units of these super-power stations, following the lines suggested in the previous article, there would be bridges provided between the 60,000-kw. units, and these for maximum safety to station operatives might be made open rather than closed. To bring out clearly the separation of units advised, these bridges were purposely omitted from the illustrations.

Further, the chief engineer's operating or instrument room might be constructed over only one unit, instruments for all units being brought together in this one central operating room. If this were done, some saving could be made by placing a flat roof directly above the fanroom, letting the coal-bunker pace walls act as parapet walls. However, it would seem that the coal-consuming capacity of each unit of this plant and the cost of coal so that perpetual boiler tests and accurate records, obtained by weights and measures, may be kept throughout the life of one of these plants.

Locating these super-power stations in large industrial communities would enormously reduce the amount of coal necessary to handle the power of such communities, for the coal consumed per unit in the super-stations, broadly speaking, is about one-half that of the isolated plant, and by making use of the byproduct turbines for manufacturing and heating steam, enormous further reductions in the use of coal are made, to say nothing of a relay power at the customer's plant, or at least a part relay to the purchased power.

In one instance, on which the writer has worked for several years, the conservation of coal is about 500,000 tons per year, and furthermore, in his judgment there will not be over five or six great stations in New England at some subsequent future date.

These large stations require such vast amounts of condensing water that they can be located only on such rivers as the Connecticut or Merrimack, or at shore ports on rivers, lakes or oceans, where the intake

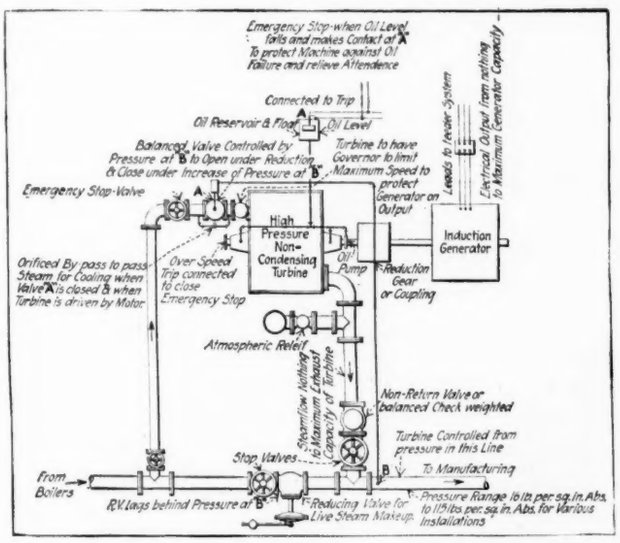

Emergency Stop when Oil Level falls and makes Contact at X To protect Machine against Oil Failure and relieve Attendence
Connected to Trip
Oil Reservoir & Float
Oil Level
Balanced Valve Controlled by Pressure at B to Open under Reduction & Close under Increase of Pressure at B
Turbine to have Governor to limit Maximum Speed to protect Generator on Output
Leads to Feeder System
Electrical Output from nothing to Maximum Generator Capacity
Emergency Stop Valve
High Pressure Non-Condensing Turbine
Induction Generator
Oil Pump
Reduction Gear or Coupling
Orificed By pass to pass Steam for Cooling when Valve A is closed & when Turbine is driven by Motor
Over Speed Trip connected to close Emergency Stop
Atmospheric Relief
Steam flow nothing to Maximum Exhaust Capacity of Turbine
Non-Return Valve or balanced Check weighted
Turbine Controlled from pressure in this Line
Stop Valves
To Manufacturing
From Boilers
R.V. lags behind Pressure at B
Reducing Valve for Live Steam Makeup
Pressure Range 16 lb. per sq. in. Abs. to 175 lbs. per sq. in. Abs. for Various Installations

FIG. 8. DIAGRAMMATIC SKETCH OF TURBO-GENERATOR ARRANGED TO OPERATE AS A POWER-PRODUCING, PRESSURE-REDUCING TURBINE

canal and discharge canal, or conduit, from the condensers should be 1,000 ft. or more apart. Of course, the question of currents, tidal effects and many other conditions enter into this problem, but this statement is made for guidance of designers in planning a station location. Furthermore, it would not be advisable to start any super-station where the ultimate development possible would be less than 100,000 kw. It would be better not to locate in any position where an ultimate development of 240,000 kw. or 300,000 kw. was not possible. This, however, would be controlled largely by the cost of transmission lines, franchises,

money values, and innumerable other conditions that enter into a project of this size.

When otherwise practicable, it will be well so to choose locations for central stations that later full advantage may be taken of economies to be brought about by the recovery and utilization of distillates and other chemical products from coal. This is a matter at present little thought of, but likely to be of increasing importance for the future. .

To illustrate further what the celebrated engineers of the country are promulgating as to the possibilities of the great super-power stations of the near future, Figs. 9 and 10, taken from the March 16, 1920, issue of *Power*, with additions, show graphically what is being seriously thought of.

This super-power zone, as shown in Fig. 9 takes in the area between Boston and Washington and extends inland from the coast 100 to 150 miles. The suggested transmission lines from the hard and soft coal fields, Niagara Falls, Cedar Rapids and from main hydroelectric plants are shown by Fig. 10.

From investigations and research I have found that there is a 300,000-kw. load, not including the steam-railroad electrification, within a radius of fifty miles from Newburyport or Beverly, Mass., which could be tied in with the great water-power developments at Manchester, N. H., Lowell and Lawrence, Mass.; and with the great development and proposed developments of the Edison Company, of Boston, Mass., the conservation in this power zone alone amounts to about 500,000 long tons of coal per year, conservatively speaking, with all the attendant advantages in the conservation of coal, money and men. The project considers the use of the river banks and railroad rights-of-way for transmission lines, and placing a station of that kind in the northeastern range of the proposed

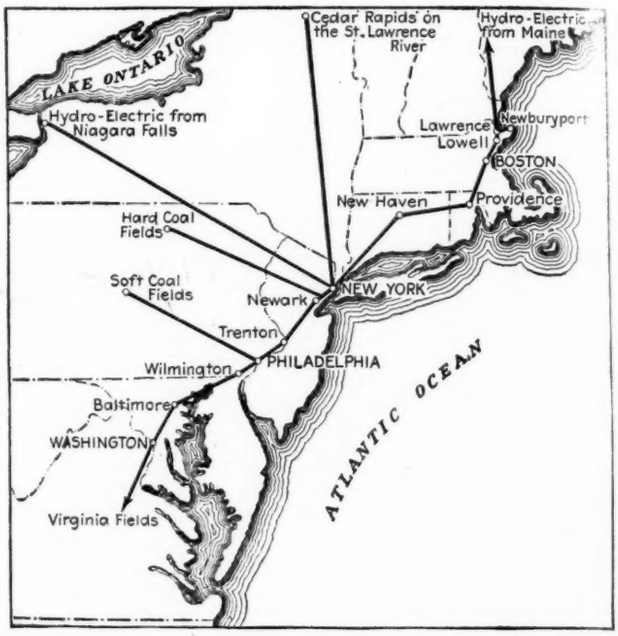


FIG. 10. SUGGESTED POWER-TRANSMISSION LINES FOR SUPER-POWER ZONE

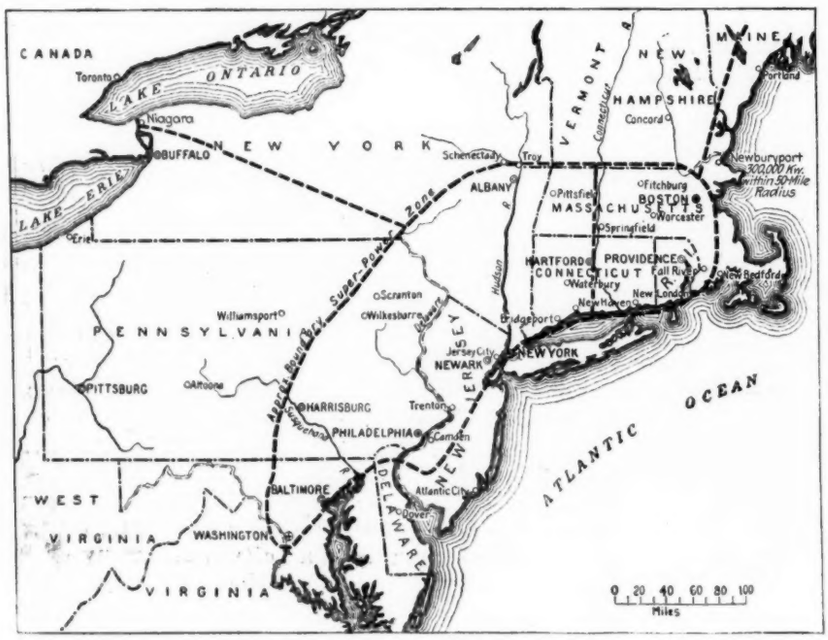


FIG. 9. MAP SHOWING APPROXIMATE SUPER-POWER ZONE

super-power zone illustrated by Fig. 9 would reinforce in a splendid manner the loop transmission line suggested.

Further, there is a vast amount of coal in Nova Scotia which, if used as pulverized fuel, would make two methods of shipment to this point by water—Nova Scotia coal and coal from the Virginia fields. This would relieve the congested freight situation of this thickly settled manufacturing district.

A cross-tie in this loop in New England and somewhat paralleling the Connecticut River and its hydroelectric and large steam developments is suggested. This would further substantiate and augment the eastern part of the super-power zone loop in New England and would also further relay the great power demands of New York City and vicinity. There are other untold resources in New England for such a project as has been outlined herein.

The time will come when no company or individual will be allowed to operate any plant at a thermal efficiency of less than a predetermined percentage; neither will any company be allowed to operate any turbines or equivalent machinery condensing when they could be operated non-condensing and the exhaust steam used in heating and manufacturing, or when purchased power from a large super-station can be advantageously made available.

In other words, as coal and oil, in fact, all known fuels, are non-renewable, natural resources, the general public will be forced to use the utmost care in their consumption.

Nothing new has been advanced, but an effort has been made to bring out clearly important facts, which are of interest to all who have to do with power-plant problems of the present or near future.

The Compressed-Spruce Pulley

Spruce of the Pacific Northwest came into its own during the war, being found excellent for airplane uses. Now comes the announcement of another application of it which promises as much for power transmission as it did for the air service. R. L. Watts, of the St. Paul & Tacoma Lumber Co., and F. J. Walsh, consulting engineer for the Port of Tacoma, Washington,

FIG. 1. LAMINATED PIECE SHOWING ONE END COMPRESSED AND ONE END NOT COMPRESSED

while pressing laminated spruce to make the glue stick fast, discovered that very great pressures did not splinter and did not materially spread the wood, but made it extremely hard and dense. This led to the application of the compressed spruce to power-transmission pulleys, which they are now manufacturing under the name of Watts & Walsh Co., Tacoma, Wash. The strips of wood or laminations in the pulleys are originally $\frac{3}{8}$ in. thick; the pressure applied for compressing is at present 100 tons per sq.ft., though a press capable of 2,500 tons per sq.ft. will be used later. The pulleys are available in all sizes.

Fig. 1 shows a laminated piece with the upper end the original width and the lower end compressed. Fig.

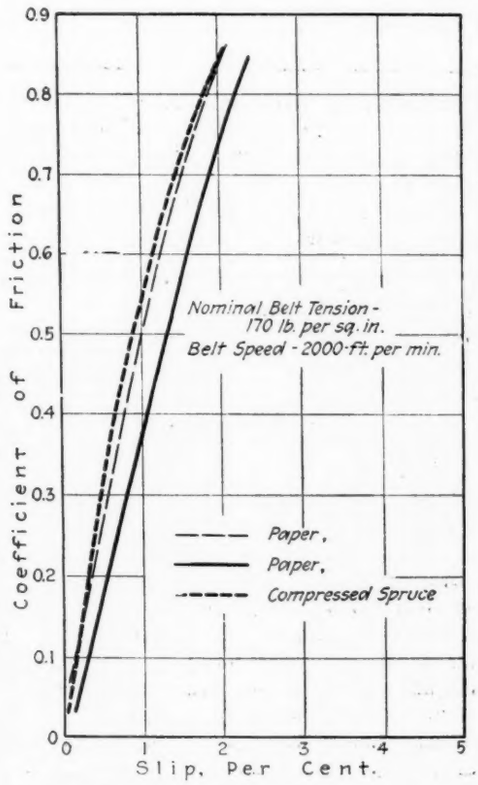


FIG. 2. PERFORMANCE-TEST RESULTS, CONDUCTED BY PROFESSOR GEORGE S. WILSON, UNIVERSITY OF WASHINGTON

2 shows performance curves obtained in tests conducted at the University of Washington by Professor Wilson, of the department of Mechanical Engineering. Fig. 3 shows a compressed-spruce pulley 36 in. in diameter,

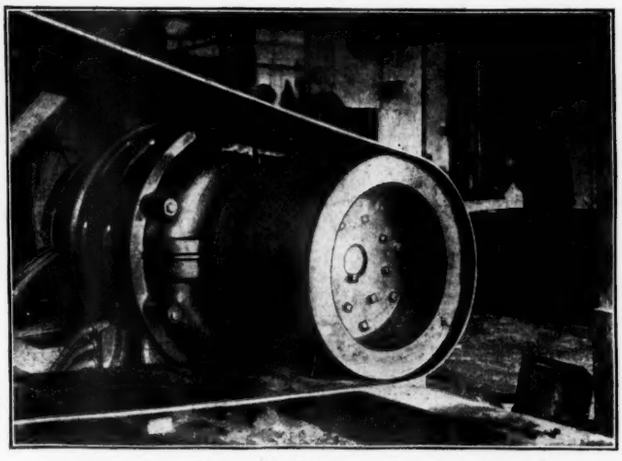


FIG. 3. COMPRESSED SPRUCE PULLEY ON 250-HP. MOTOR DRIVING GANGSAW, EXTREMELY VARIABLE LOAD, SWINGING FROM NO LOAD TO 400-HP.

31-in. face; the distance between flanges, where the pulley is fastened to the shaft, is but 5 in. The motor is of 250-hp., with extremely and suddenly variable load from a gangsaw which it drives.

Paralleling Two Alternators When They Rotate in Opposite Directions

By B. A. BRIGGS

It is shown why, when two alternators are revolving in the same direction and connected to operate in parallel, they cannot be connected in parallel if the direction of rotation of one of the machines is reversed, until the connections on one phase of this machine is reversed.

IN THE article, "Operating Two Alternators of Opposite Polarity in Parallel," in the May 18th issue, it was shown that changing the direction of the exciting current through the field coil of one of a number of alternators does not prevent it being connected in parallel with other machines, except where two alternators are operated in parallel and are connected to the same prime mover. In this case the rotating elements, being connected permanently together, cannot seek their true phase relations, therefore this relation must be determined by test before the machines are put into service. The next question that arises is, "What would be the effect if the direction of rotation of an alternator that is operating in parallel with other machines is reversed?"

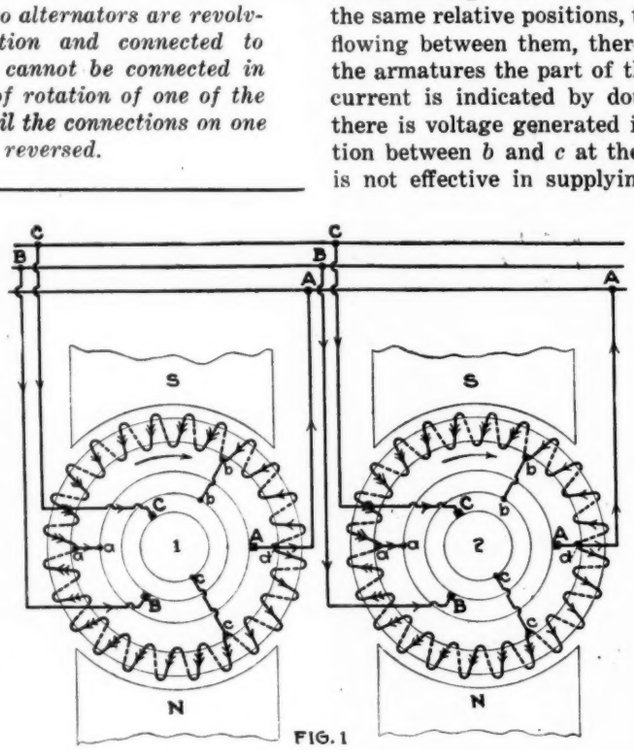


FIG. 1

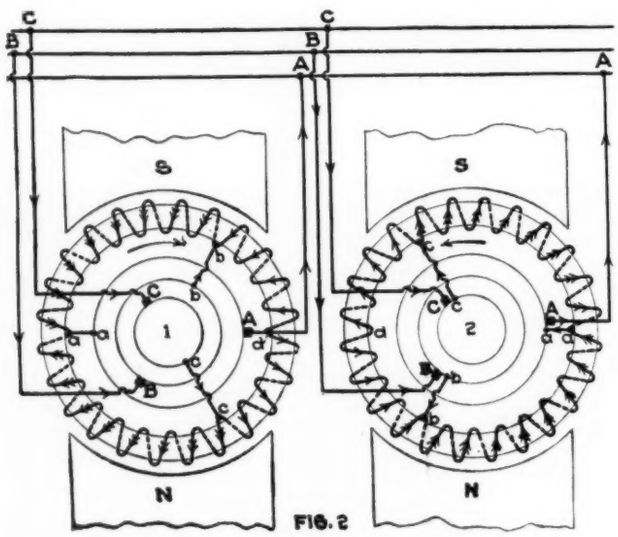


FIG. 2

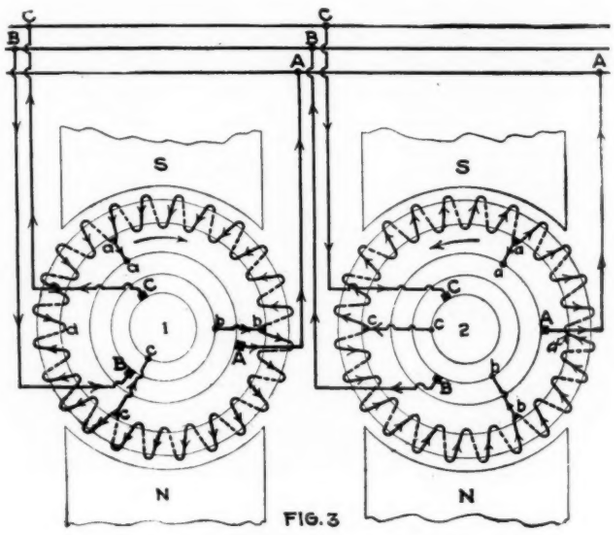


FIG. 3

FIGS. 1 TO 3. SCHEMATIC DIAGRAMS OF TWO ALTERNATORS CONNECTED IN PARALLEL

In Fig. 1 is represented two three-phase alternators connected symmetrically to a set of busbars, and both machines revolving in the same direction. In each machine the *A* terminal is positive and the *B* and *C* terminals negative. Since the armatures are in exactly the same relative positions, there will be no cross-current flowing between them, therefore they are in phase. In the armatures the part of the winding that is supplying current is indicated by double arrowheads. Although there is voltage generated in the conductors of the section between *b* and *c* at the instant shown, this section is not effective in supplying a current to the external circuit, since the voltage generated in the conductors between *b* and *d* opposes that between *d* and *c*. The volts generated in these two sections are equal and opposite, consequently the resultant voltage is zero, and no current will be supplied from this section. Assume that the direction of rotation of No. 2 machine is reversed, as indicated in Fig. 2 by the curved arrow. If the armature of this machine is turned through 180 deg. from the position in Fig. 1, or 180 deg. from the position of machine No. 1, Fig. 2, it will be seen from the arrowheads that the machines are again in phase. The *A* terminals are positive and the *B* and *C* terminals negative, and the voltages generated in the *ab* and *ac* sections of both armatures are equal. Although the *ab* section in the left-hand machine is under the S pole, and in the right-hand machine under the N pole, and vice-versa for the *ac* sections, the voltage is in the correct direction for the machines to be

in synchronism at the instant indicated. From this the conclusion might be drawn that the machines can be synchronized, but this condition represents only one instant in the revolution, and although the machines might be in synchronism at this instant, it is possible that they are out of synchronism at all other points. Therefore, before a decision can be made, other points in the revolution must be investigated.

In Fig. 3 both armatures have been revolved through 60 deg. from the position in Fig. 2, the armature of No. 1 turning clockwise and the armature of No. 2 turning counterclockwise. The arrowheads indicate that although the *A* terminals are both positive, and therefore apparently have the correct phase relation, terminal *B* on machine No. 2 is positive, and *B* on machine No. 1 is negative, and vice versa for the *C* terminals. Consequently, the *B* and *C* terminals on the two machines are out of phase, and if these machines are connected together under this condition a very heavy current will flow between them. Therefore the generators cannot be synchronized if they are rotating in opposite directions and are connected systematically to the busbars. A comparison of Figs. 2 and 3 will indicate what has happened. In Fig. 2 it will be seen that similar taps on the two armatures are 180 deg. apart; that is, the *a* tap on armature No. 2 is 180 deg. away from the *a* tap on armature No. 1, likewise for the *b* and *c* taps. In Fig. 3 we find the taps occupying positions in space only 60 deg. apart. If it were possible to maintain similar taps 180 deg. apart in space, the machines would remain in synchronism, but since they are turning in opposite directions, the position of similar taps with relation to each other is continually changing. In the article previously referred to the polarity of one machine was reversed, and this machine was found to be in synchronism with the other machine when similar armature taps on the two machines had relative positions in space 180 deg. apart. The machines then remained in synchronism at all points in the revolution, since they were turning in the same direction, and it was possible to maintain a fixed relation between the two armatures. In Fig. 2 the armatures are turning in opposite directions, consequently the relation between the positions of similar taps on the two armatures are continually changing, and therefore their voltage relation.

The next thing to consider is what to do to make it possible to get the two machines in parallel when rotating in opposite directions. This can be done by crossing any two leads on the machine that was reversed—in this case machine No. 2. If there are only two machines, crossing the lead on either machine would make it possible to synchronize them; but if the phase of the busbars is reversed, then any induction motors on the system would be reversed, consequently the change should be made on the machine that is being put into service. Fig. 4 is the same as Fig. 3, except that leads *B* and *C* of machine No. 2 have been changed at the busbars; that is, *C* brush has been connected to *B* bus and *B* brush connected to *C* bus. It will now be seen that the leads going to the *A* and *C* busbars are positive, and to the *B* bus negative, and since the armatures are in a position where each will generate the same voltage, the two machines are in synchronism at this instance.

The armatures, Fig. 5, have revolved 60 deg. in the direction of the curved arrows from the position shown in Fig. 4. In this position the terminals connecting

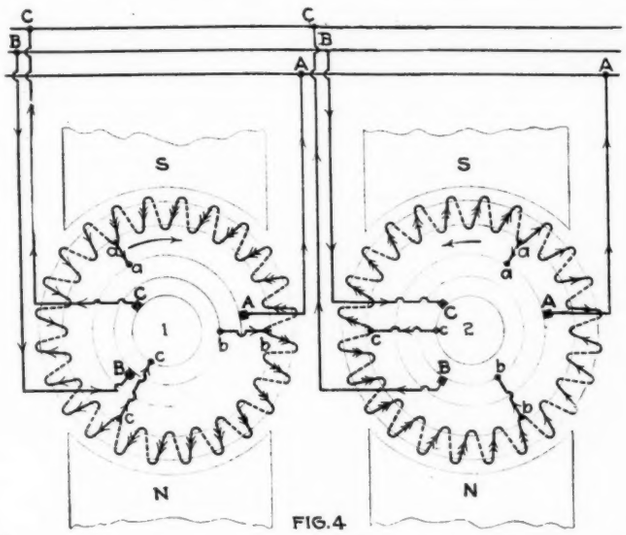


FIG. 4

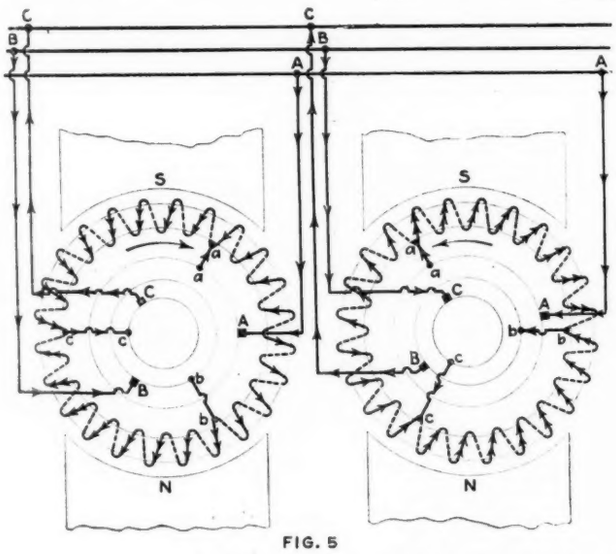


FIG. 5

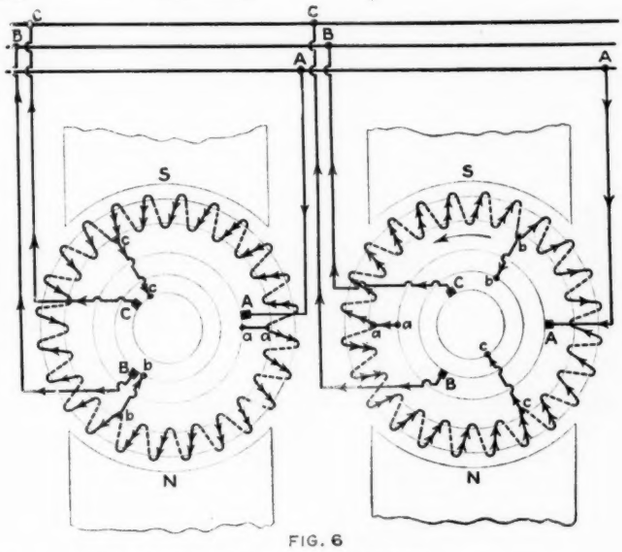


FIG. 6

FIGS. 4 TO 6. SAME AS FIG. 3, EXCEPT "B" AND "C" LEADS ARE INTERCHANGED

to *A* and *B* busbars are negative, and the terminals connecting to *C* busbar are positive, and since the armatures are in a position to generate the same voltage, they are again in synchronism, as in Fig. 4. In Fig. 6 the armatures have turned through 60 deg. from the position in Fig. 5, and an inspection will show that the voltage relation between the two machines is correct for parallel operation. From the foregoing the conclusion may be drawn that if two alternators are connected properly for parallel operation when both machines are revolving in the same direction, if the direction of rotation of one of the machines is reversed, two of the leads must be reversed on this machine before it can be again parallel with the other machines. This discussion refers to three-phase machines. With two-phase machines care must be exercised to cross the lead on either phase of the machine whose direction has been reversed.

When two alternators are geared to the same turbine, one revolving in one direction and the other in an opposite direction, to connect the machines to operate in parallel tie a like lead on each machine together. For example, the *A* leads on each machine are connected together. Then the *B* lead on one machine is connected to the *C* lead on the other machine, and vice versa, as was done in Figs. 4 to 6. Then if the revolving elements are placed in the same relative position on each machine, as explained in the article, "Synchronizing Two Alternators When Driven by One Turbine," page 568, *Power*, Oct. 7, 1919, and the exciting current made to flow through the field coils in the same direction, the two alternators should come up to voltage in exact synchronism.

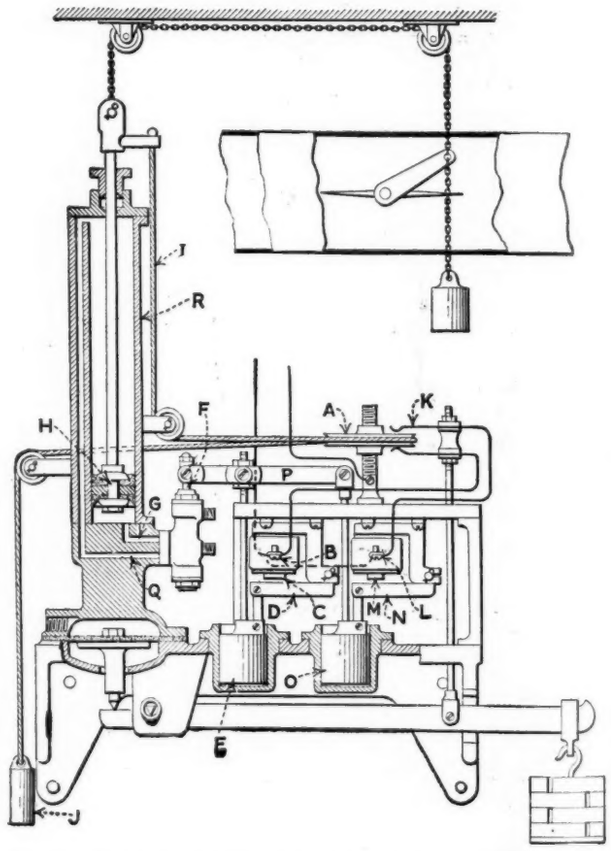
R. K. Hydro-Electric Pressure Regulator

There has recently been developed a pressure regulator designed to eliminate all erratic action in operation. The scale beam is free to respond accurately to variations in pressure of ¼ lb. or less and to transmit its readings, by means of an electric contact, to limit the movement of the motor plunger. The variations in pressure are transmitted to a pilot valve which controls the movement of the motor by means of electric magnets. One magnet controls the upward movement of the plunger and another controls the downward movement, the pilot valve normally being held in a neutral position, when no pressure can be admitted to the motor cylinder.

The motor travels by stages. The plunger is moved step by step with a well-defined period of rest between each stage of its travel. When a change in pressure takes place, the plunger is moved rapidly to the next succeeding stage and comes to rest and remains in that position until a change in pressure again takes place; in this way the plunger assumes at all times a position which corresponds with the pressure and thereby regulates the air supply to the furnace in the quantities required.

The operation of the regulator, which is made by the Ruggles-Klingemann Manufacturing Co., Salem, Mass., will be understood from the following: Wherever the steam pressure exceeds a predetermined amount for which the scale beam is weighted, an electric contact is made with the underside of the contact disc *A*, thus sending an electric current through the coil *B* and energizing the magnet *C* and the attracting armature *D*, which raises the dashpot plunger *E* and the valve spindle *F* and admits pressure through the port *Q* to the underside of plunger *H*. As the plunger moves upward, it revolves the contact disc *A* by means of a cord *I*, which extends to the top of the plunger rod, the opposite end of the cord being provided with a weight *J*, so as to take up the slack and place sufficient tension on the cord to drive the contact disc.

The contact disc moves in a direction to break the current and cause the armature to be de-energized, which allows the dashpot plunger *E* to settle to its bottom position and return the spindle *F* to its neutral positon, which in turn brings the plunger *H* to rest. If the steam pressure should continue to increase, the operation will be repeated, the plunger moving up to a second position, and so on, making from ten to twelve stops before the stroke is completed. Whenever the steam pressure decreases, the contact point *K* engages the top of the contact disc *A*, which sends an electric current through coil *L*, energizing the magnet *M* and attracting the armature *N*. This raises the dashpot plunger *O*, and as the lever *P* is fulcrumed on the dashpot rod, the spindle *F* will be lowered, thus opening the port *Q* and allowing the pressure to enter the top of the cylinder *R* and force the plunger downward. As the plunger moves, it turns the contact disc *A*, which breaks the circuit, and the magnet *M* is de-energized, allowing the armature to be released and the dashpot plunger *O* to settle into its bottom position and bring the plunger *H* to rest, the plunger making regular stops on the downward stroke with short periods of rest the same as on the upward stroke.

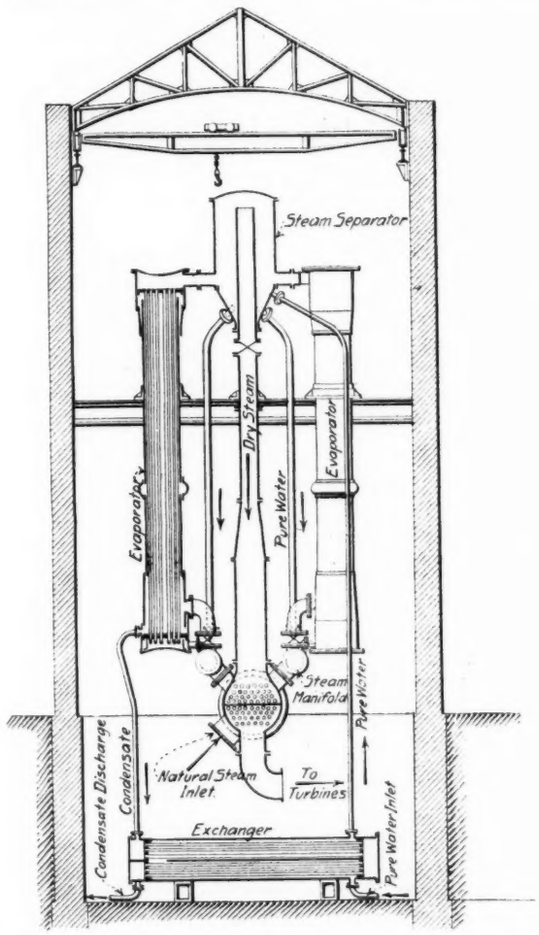


SHOWING DESIGN OF ELECTRIC-PRESSURE REGULATOR

Steam from the Earth

In *Power* for Jan. 13 was described the use that is being made from steam obtained from borings in the volcanic region of Italy. Readers will be interested in the further information that the publication of this article has brought out.

The natural steam being impregnated with impurities that are likely to attack the turbine, it has been necessary to use the heat of this steam for the production of pure steam usable in the turbine, instead of using it direct. This transformation is effected in vertical evaporators with long tubes upon the Kestner system. The battery of evaporators is composed of thirty units, each having a heating surface of 150 sq.m. (about



KESTNER EVAPORATORS FOR PRODUCING PURE STEAM FOR TURBINES FROM THE HEAT OF VOLCANIC STEAM IN ITALY

1,600 sq.ft.). The tubes, which are 7 m. long (about 23 ft.) are of aluminum, the only available metal that resists the corrosive action of the steam from the Soffioni.

The natural steam comes to the evaporators at a pressure of about two atmospheres and considerably superheated. The steam is produced in the evaporators at a pressure of 1½ atmospheres and is superheated before being introduced to the turbine. Each of the units can evaporate 5,000 to 6,000 kg. (11,000 to 13,000 lb.) of water per hour.

The evaporator units are arranged in pairs, as shown in the accompanying section, and each group of five pairs is supplied from the same superheater. Steam from the Soffioni enters at the natural-steam inlet, passes through the tubes of the superheater and then through the steam manifold to the evaporators. The condensate passes, as shown, from the bottom of the evaporator through the tubes of the exchanger and is finally discharged.

Pure water enters as shown, passes over the exchanger tubes and enters the bottom of the steam separator, where it mixes with the separator drip and is led to the bottom of the evaporators. Passing up through the tubes, this water is evaporated, any priming is taken out in the separator, and the dry steam goes down to the superheater and then to the turbines. It is claimed that this evaporator apparatus gives a thermal efficiency of 88 per cent.

Coal or Oil Fuel for Refrigerating Plants?

BY J. E. PORTER

In comparing coal with oil fuel for refrigerating plants no fixed rule can be laid down that will apply to all plants, owing to the different conditions met with in each individual installation. Comparing the average calorific values of the two fuels, placing coal at 11,000 B.t.u. per pound and oil at 18,500, it is evident that the oil has the advantage. It should not be taken for granted, however, that oil will be the cheaper fuel, as the price of oil relative to coal will determine this factor. The only logical and practical way to ascertain which is the cheaper fuel for a particular plant is to make a complete survey and take into consideration the cost of every item entering into the process of burning each kind of fuel. The items to be considered in the burning of coal are the original cost per ton at the mines, freight to destination, unloading at the bunkers, losses in heat value while in storage, handling between bunkers and furnaces, removal and disposal of ash and general upkeep of the furnace.

Oil can be delivered to the boiler furnace more cheaply than coal as it is handled mechanically at all times, so that a considerable saving in labor is to be expected. The several advantages usually accredited to oil as a fuel are that for the same heat value, oil occupies much less space than coal. The firedoors of the furnace do not have to be opened, reducing excess air to a minimum, giving a more even temperature and better combustion and resulting in higher capacities and efficiencies. The fires are more easily regulated to meet load requirements; there are no losses in heat value during storage. In burning oil there is no ash and very little smoke or soot if the burning is accomplished in a properly designed furnace and burner. Under such conditions it is a much cleaner fuel than coal, but the reverse is true if proper conditions are not maintained.

Under favorable conditions a pound of fuel oil will evaporate from 14 lb. to 16 lb. of water, while the evaporation from a pound of coal will range between 7 and 10 lb. Assuming a distilled-water ice plant and allowing 25 per cent to cover losses, it is necessary to evaporate 2,500 lb. of water for each ton of ice manufactured. Placing the evaporation by oil at 14 lb. of water and by coal at 8 lb., it will require about 180 lb. of oil or 313 lb. of coal to evaporate the 2,500 lb. of water. Taking the present price of fuel oil at $3.15 per barrel, the fuel costs per ton of ice would approximate $1.75; with coal at $5 per ton in the bunkers the fuel cost per ton of ice figures about 78c. From the standpoint of fuel alone at the relative price quoted, coal

has a decided advantage. The saving in labor and the higher efficiency maintained by the use of oil would lessen this advantage to some extent, although not enough to overcome the difference of 97c. per ton of ice made.

Although the price quoted on fuel oil was given to the writer recently by a refining company at Oklahoma City, there are no plants in the vicinity paying $3.15 per barrel for oil. The plant using this fuel had contracted for its supply some time ago, and it is probable that its fuel cost ranges from $1 to $1.25 per ton of ice. On this basis the oil per barrel would cost from $1.80 to $2.25. Although 10 tons of ice per ton of coal is quite feasible, the usual run of plants will not average more than 5 tons of ice per ton of coal, so that with coal at $5 per ton the fuel per ton of ice would cost $1. If the prices just quoted can be obtained, there is little choice between the two fuels. Considering the scarcity of both oil and coal, however, it is largely a case of burning the fuel that can be more readily obtained, whether it should happen to be the cheaper or not.

The problem that confronts the refrigerating engineer of today is to burn the kind of fuel he is able to get with the greatest degree of efficiency. To do this a furnace must be designed to suit the particular fuel used. There is no reason for anyone to think that any design of burner will do or that the burner can be set into any kind of a coal-fired furnace and that high efficiency will be obtained. It cannot be done. There is just as much difference between the installation for burning oil and for burning coal as there is between a pump and an injector. Both perform the same duty, but in an entirely different manner and with different results. For either fuel a properly designed furnace and for oil a burner that has been approved are required. It may cost a great deal of time and money to get the furnaces just right, but the expense will be warranted and it will probably save shutting down in the middle of the season.

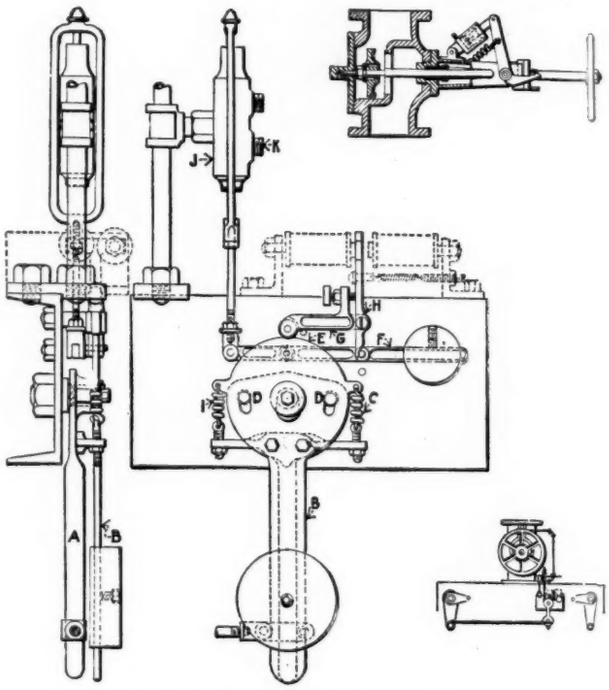
Clock-Pendulum Precision Speed Limit

A speed-limit device for the control of steam engines has recently been designed by E. E. Clock, chief inspector of the turbine and engine department of the Fidelity and Casualty Co., of New York. Patents are pending. The operation of the device is as follows: It is placed so as to be conveniently connected to any reciprocating part of the engine. There are two pendulums. One is positively driven, designated as *A*, and moves through a fixed arc; the other, or weighted pendulum, *B*, is in line and swings with the positively driven one until such time as the oscillations become fast enough to overcome the stabilizing springs *C*, which tend to hold the weighted pendulum *B* firmly on the two pins *D* projecting through the curved slots in the disc attached to the weighted pendulum *B*.

As the positive-driven pendulum moves to the right and starts upon the return stroke faster than the speed for which it is adjusted, the right-hand stabilizing spring *C* is overcome, the disc *E* rises off the right-hand pin *D*, swings around the left-hand pin *D*, becoming eccentric to that pin and lifting the lever *G*, which carries a roller above but clear of the disc *E*. Raising the lever *G* moves the top of the latch lever *H* to the right, the bottom or latch end to the left and drops the weighted valve-operating lever *F*, which opens the pilot valve *J*, resulting in a flow of water of condensation under full boiler pressure through the connection to the operating cylinder, which is located on the throttle-valve bonnet.

This unlatches the automatic throttle valve and gives it a start. At the same time, the threaded sleeve being released, the flow of steam, together with the piston effect of the full area of the valve stem, closes the throttle promptly.

Restoring the valve-operating lever *F* opens a drain below the operating piston and the spring *I* causes the piston to recede, when the throttle valve may be opened and the apparatus is ready to repeat its former action at the slightest overspeed. It will be seen that there can



DETAILS OF SPEED-LIMIT DEVICE

be no stopping of the engine through leakage of the pilot valve, as the drain is open at all times until overspeed action occurs.

The magnets shown are to be used if either open- or closed-circuit electrical remote control is desired. This electrical remote-control device is auxiliary and may be omitted without interfering with the action of the speed limit.

It is clear that this speed limit is suitable for use in connection with any type of valve designed to operate with pressure or release of pressure.

In commenting on the failure of a plugged tube in the boiler of a locomotive at Allerton Bywater Colliery, the Engineer Surveyor-in-Chief to the Board of Trade condemns the practice of stopping leaky tubes by means of plain tapered plugs driven into the ends, says *The Engineer*. In the case in question, the plug was 4½ in. long by 1⅛ in. in diameter at the large and 1½ in. in diameter at the small end. It was driven into the tube by means of a 7-lb. hammer, but blew out, with fatal results, at a pressure of about 115 lb. per square inch.

EDITORIALS

One Pound per Horsepower

ONE of the most marked characteristics of the human being is his interest in sporting events of all kinds. The two greatest stimuli to the normal male are the opportunities of beating the other chap and of breaking a record.

In the early days of the last century the Watt engines used for pumping water from the tin mines in Cornwall had their performance much improved through competition among the mines. The favorite bet in that section of England was on the number of gallons of water pumped each week per bushel of coals.

An interesting field for competition, which should arouse the sporting instinct of the engineer, is in the reduction of weight of power plants, especially as the alluring figure of one pound per horsepower is distinctly above the horizon. Twenty pounds per horsepower made the automobile possible; five pounds per horsepower made the airplane possible. What may we not expect from one pound per horsepower?

The heaviest source of power in common use is animal power. A horse weighing one thousand pounds will develop eight-tenths of a horsepower for eight hours. For the continuous twenty-four-hour development of one horsepower, 3,750 pounds of horse would be necessary. Man is a little better on that basis. Under favorable circumstances he can develop one-seventh of a horsepower for eight hours, which would give him a weight of 3,150 pounds per horsepower if the individual man weighs one hundred and fifty pounds and develops power continuously. The average stationary steam plant, including boilers, engines, condensers, chimney, and the numerous auxiliaries, the water in the boiler and the circulating water, has a weight which is high and extremely variable. All condensing steam plants must be heavy because of the necessity of carrying a large weight of circulating water. A modern locomotive develops about two thousand horsepower and weighs 300,000 pounds, giving a weight of one hundred and fifty pounds per horsepower. This, of course, includes the running gear, which does not properly belong to the power plant. It is probably possible to make a non-condensing power plant of good size which would not weigh more than forty or fifty pounds per horsepower. It might be composed of boilers of the express marine type which would weigh sixteen to twenty pounds per horsepower, including the weight of water, and of turbines which would weigh fifteen pounds per horsepower, and of the necessary auxiliaries.

The only possibility of obtaining light power plants is by the use of the internal-combustion engine. The Diesel engine with its high efficiency has not yet been brought down to a reasonable weight. In Europe, weights of fifty to sixty pounds per horsepower are reported. In this country the weights are usually four to six times greater. The automobile engine, including the radiator and jacket water, which are necessary parts of the power plant, will probably average about ten pounds per horsepower. The aëronautical engine of the water-cooled type has been brought down to a total weight, including radiator and water, of approximately two and one-half pounds per horsepower. The air-cooled aëronautical engine should be, and is, much lighter. Varying reports about the A. B. C. English airplane engine indicate a weight per horsepower somewhere between 1.3 and 1.7 pounds. This seems to be the best figure so far.

Another improvement, however, looms in sight. The horsepower of an internal-combustion engine is directly proportional to the pressure of the mixture taken in. By the use of a centrifugal compressor (supercharger) the admission pressure can readily be doubled, thereby doubling the power of the engine. This device has been used at high altitudes for maintaining the power of an engine. It could also be used on the ground for increase of power beyond the normal ground horsepower. Such a device would weigh not more than one-fourth the weight of the engine and would thereby increase the power per unit weight by sixty per cent, if its use did not necessitate such changes in the engine as to cause the weight of the engine to be increased. It is certain that the attempt to double the intake pressure in any of the existing air-cooled aëronautical engines would lead to overheating of the piston and cylinder as a result of the increased weight of fuel burned, but modifications in design could take care of this increased heat. The way, then, seems open for those who desire to follow it. It will not be very long before one pound per horsepower is a realized fact.

Power-Factor Correction an Economic Issue

POWER-FACTOR correction in an alternating-current circuit is a problem that has existed ever since the installation of the first induction motor. However, it is only within recent years that serious attention has been given to improving the phase relation between the voltage and current in alternating-current circuits. The real significance of the interest centered in power-factor correction at this time is found in the statements, recently made, that "the power companies today can sell more power than they can finance the necessary extension for, consequently, one of the most difficult problems in the operation of utilities is that of finance," and that "if the power factor of all connected equipment utilizing a certain company's service could be raised to unity, the entire electrical system, including generators, transmission lines, substations and transformers could be made to carry thirty-five thousand kilowatts more load than it carries at the present time." In the latter case the only additional investment required to accomplish this would be for an increase in the turbines and boilers at the power plant to bring them up to the greater capacity of the electrical system, resulting from the higher power factor. On the other hand, the installation of a thirty-five-thousand kilowatt extension would

require an investment of between four and five million dollars. If the power factor of the system was increased to unity, the service would be materially improved, the losses per kilowatt transmitted considerably reduced, and the operating costs remain practically the same. Where, even if the thirty-five-thousand kilowatt additional capacity is installed the service would not be improved, the losses per kilowatt transmitted would not be decreased, the operating cost would be increased, besides the larger capital charge required to pay a reasonable return on the increased investment.

To improve the power factor and obtain the full advantage resulting therefrom, the correcting must be done at the load. Under such conditions the losses in the customers' distributing system are reduced and voltage regulation is improved, both of which tend toward better service. Besides this the wattless current is reduced all the wak back to the station, thus increasing the capacity of the entire system. The satisfactory working out of this problem is one that requires close co-operation between the customer and the power company, and its solution is one that will result in mutual benefits to all parties concerned.

Power From the Tide

FOR a satisfactory solution of the economic problems before the world today, due to the high cost of labor and materials, shortage of production, etc., the attention of the various nations has been turned toward a greater production and use of power. Even in some of the most backward countries surveys are being made of available power resources, and methods are being considered how best to develop these resources. In the more progressive countries, where the production of power has become a more or less highly developed science, not only are the available sources that have proved commercially possible of development being carefully considered, but those sources and methods that have in the past been abandoned on account of their lack of commercial possibilities are now being carefully scrutinized. On account of the greatly increased cost of power production from coal, it may now be economically possible to develop some of the sources that a few years ago were beyond any such a consideration.

Various schemes have been suggested for developing power from the tide, but up to the present time all of these have proved impractical or uneconomical from the commercial side. And it is doubtful if in this country we have approached a condition where the development of power from the tide is commercially economical, even under the most favorable conditions. Nor will we until the present available water power of our rivers is more completely developed and our sources of fuel more nearly exhausted than at present. However, in a country like England, where practically the only available local source of power is coal, with very limited water powers on the rivers, it may be feasible to develop tidal power. According to the *Electrical Review* (London) the British government is considering preliminary plans inquiring into the possibilities of utilizing the available water power of the country. Among these plans are those which pertain to the development of power from the tide at the mouths of a number of rivers. It has been pointed out that since the time of the tide varies considerably in the different rivers, it may be possible to take advantage of these variations to increase the daily period power could be generated. This scheme may have possibilities, but whether the time has arrived when the cost of power from coal is such as will make the scheme a commercial one is questionable. Nevertheless, the consideration of the matter by the British government indicates how vitally important the power supply has become to the industrial development of that nation.

Almost every scheme for the development of tidal power has been associated with the idea of storage of power for use during the period of the day when the tide is not available. The electrical storage problem is one of the stumbling blocks to the successful development of the scheme. What appears to be a better and more logical solution would be to operate the tidal power plant in conjunction with a system of steam plants or hydro-electric plants, the latter on rivers where water storage is available. These plants could then carry all the load that the tidal plant could not. Unfortunately, in this country, locations where such a scheme might be worked out are very limited, and where such localities are available, they are, in general, considerable distances away from large industrial developments. Therefore, the development of tidal power in this country, at least, is hardly a matter for present consideration, although it may be a commercial possibility in countries that are not so abundantly supplied with fuel and sources of water-power development.

Flanges for Steam-Flow Meters

A LITTLE forethought in planning the details of a power plant will often result in considerable savings. For example, there may be no present thought of using a steam-flow meter, but by and by the need or the appreciation of the advantages of such an apparatus may develop.

The devices used to give sufficient pressure drop in the pipe for operating the meter usually require flanges between which they are installed, preferably preceded and followed by straight courses of pipe of a length equal to a few times its diameter. The insertion of such flanges in an existing pipe line is disturbing, time-consuming and expensive, and the necessity of it may prevent or delay or make more difficult to get approval for the installation of a meter, the use of which would result in saving many times its cost. Such flanges can be put in at little or no extra cost in the original installation.

Great Britain is using every means possible to assure a world-wide oil supply for her own navy and her own people. Some have criticized this policy, but it looks to us like a very natural and a very wise precaution. It would pay the United States to imitate rather than criticize in this case. We are going to need more and more oil, and if the United States Government does not see to it that we have access to an adequate supply, no other government is likely to bother about it.

Never mind if the railroads cannot haul that extra coal you ordered for next winter's use. We all hope that conditions will be better before the summer is over. Whatever happens, your chances of getting coal hauled during the summer are better than when the roads are handicapped by ice and snow.

CORRESPONDENCE

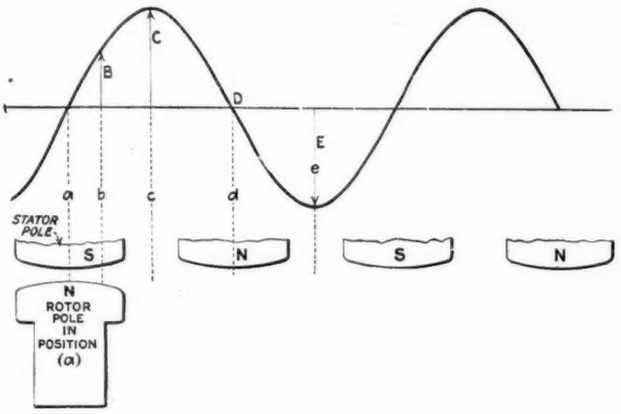
What Happens When a Synchronous Motor Is Caused to Pull Out

The Feb. 17 issue of *Power* contains a letter by F. L. Fairbanks on "What Happens When a Synchronous Motor Is Caused to Pull Out?" in which attention is invited to the danger to both apparatus and life due to the "pull-out buck" and "electrical pile-up" of synchronous motors. The danger, pointed out in the article, is the possible failure of direct-connected flywheels under the influence of the "pull-out buck." The article does not make clear just what a "pull-out buck" is, but there is no question left in the reader's mind regarding the danger of using a motor with such a formidable characteristic.

What is needed to help clear up the situation is not so much the redesign of flywheel arms as an explanation of a "pull-out buck"; although, if, as mentioned in the article, flywheels are to withstand such shocks as that produced by the piston driving a mass of water or metal through the cylinder head, then, unquestionably, adequate strength would require greater section in flywheel arms and perhaps in other "links in the chain," than is used in ordinary practice.

The implication in the letter regarding the danger of directly connecting synchronous motors to flywheels is not justified by the facts. Too many synchronous motors have operated safely and successfully for years and have survived more serious circumstances than the "pull-out buck" can possibly create, to justify such alarm now. The following explanation of the action of a synchronous motor at breakdown brings out, incidentally, some of the fundamental reasons why we might expect the facts of synchronous-motor history to be as they are.

In the following discussion it is assumed that the new terms "pull-out buck" and "electrical pile-up" are intended to mean the electrical torque of the motor at and immediately following breakdown—in other words, the electrical force acting on the poles of the rotor when the motor pulls out of synchronism. What is the character of that force? Is it a very large unidirectional force (a "buck") applied "instantaneously," as suggested in the article, or is it, instead, a force which, under circumstances of breakdown, is applied gradually, not abruptly, and which constantly changes direction as the rotor and stator poles slip by each other? It is the latter and is represented in the figure. When a rotor N pole is directly under a stator S pole—that is, position *a* in the figure—the torque is of zero value. In position *b* full-load torque value is obtained. When the rotor pole is in position *c*, a maximum, or "pull-out," torque is developed. At *d* the torque is again zero, and at *e* the turning effort is at maximum, but this time it is in an opposite direction to that at *c*; that is, it is now in a direction to stop the motor. Position *b* is the position of the rotor pole with respect to the stator pole when the motor is carrying a constant load torque equal to *B*. First this force is in a direction to maintain motion, then in a direction to retard it. The highest value of this alternating force may be any value between, say, the force corresponding to 1½ times normal load and 4 or 5 times that value, depending upon how rapidly the motor, by external means, is caused to pull out of step; that is, how fast the poles are caused to slip by each other from the very beginning of the phenomenon. The



CURVE SHOWING NATURE OF FORCE EXERTED ON THE ROTOR WHEN MOTOR IS PULLED OUT OF STEP

more rapidly it happens, the greater the maximum value until the foregoing limit is reached; then there can be no further increase.

The reason the torque is greater the faster the poles slip by each other is because the magnetic flux in the poles cannot change instantly. The flux requires a definite time to change. Thus for very rapid changes of position the flux decreases only slightly in the first few reversals, whereas for slower changes in position the flux can practically adjust itself at all times to the ever-changing pole position. In the former case the flux remains high; in the latter it decreases. The greater the magnetic flux the greater the maximum torque, and vice versa.

But before this torque, in either case, can affect the stresses in the flywheel arms, it must change the speed of the rotating mass of the motor, which in turn tends to change the relative position of the rotor with respect to the flywheel. This produces a twist or torsion in the

shaft, and this torsion is exerted on the flywheel arms. To illustrate, if the rotor of the motor had negligible mass or inertia, then the motor forces would be transferred in full upon the shaft and flywheel arms. On the other hand, if the motor had a relatively very large inertia, the motor forces would be practically all absorbed by this inertia without appreciably affecting the shaft or flywheel arms. Between these limits, if the torsional elasticity of the shaft is neglected, the fraction of the motor force that is applied to the flywheel arms is determined by the relative value of flywheel and motor inertia. Thus, roughly, the following relation would hold:

Flywheel Inertia as Fraction of Motor Inertia	Fraction of Motor Force Applied to Flywheel Arms
0	0
0.5	0.33
1.0	0.50
2.0	0.66
10.0	0.91
100.0	0.99

However, the shaft twist cannot be neglected, especially if the motor force is changing direction rapidly, because *the force applied to the flywheel arms is measured entirely by the shaft torsion;* that is, by the relative angular displacement of the flywheel and motor rotor.

The shorter the time during which a force acts on a mass the greater that force must be to produce the same speed change; and it must be again increased by the same percentage to produce the same angular displacement. Thus, 100 lb. acting for one second will produce the same speed change in a given mass as 1,000 lb. acting for 0.1 second; or it will produce the same angular displacement as 10,000 lb. acting for 0.1 second. Therefore, in order to obtain a large force in the motor, the force must alternate rapidly; but the more rapidly it alternates, proportionally less is its effect in changing speed, and less, as the square, is its effect in producing angular displacement, that is, in producing stress upon flywheel arms.

While these considerations are necessarily general, they nevertheless afford a basis of explanation for the fact that hundreds of synchronous motors with direct-connected flywheels have operated for years with no trouble from the source in question. And that is a good reason, if the foregoing discussion is not, that it is not dangerous to apply synchronous motors to apparatus involving flywheels. An isolated case of obvious mechanical failure of reciprocating parts in a compressor cylinder, thus throwing a severe shock on the flywheel, should not occasion undue suspicion of the synchronous machine that happened to be a part of the unit it is driving.

It seems certain, therefore, that under the circumstances of pull-out or breakdown, there is no danger of overstressed flywheel arms due to the motor forces, since in order to cause breakdown, either the voltage must be reduced, in which case only normal torque would be encountered, or a sudden shock must be applied to the shaft. In the first case the torque is too low to cause trouble; in the second, although it may be high, it alternates too fast to produce serious stress and is therefore not of great moment.

However, there are possible circumstances, entirely apart from conditions of pull-out, in which the higher motor forces may be involved. If when the motor is operating normally the line switch is opened and then closed again after the rotor has dropped back out of its proper phase position, it is possible to obtain a large force of relatively long duration. This condition is also approximated when, during the starting procedure, the motor is thrown from tap voltage to line voltage. If the operator hesitates between these operations, the motor will drop back. This often happens, and seems to be the worst possible condition obtainable for throwing strain upon flywheel arms. Yet, to the writer's knowledge, no flywheel has ever failed under that condition, which would at least indicate that, so far as possible strains from the motor are concerned, most of the present standards of flywheel design are adequate. However, it is well, as the letter suggests, to make sure in design, as is now probably always done, that all parts are proportioned with reference to the forces to which they may be subjected, so as to reduce the liability of failures to a minimum.

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Capacities of Steel Stacks for Oil Burning

Having occasion to use the tables for chimney capacity given in Marks' Mechanical Engineer's Handbook and finding that the values involved lay outside the tables, I have devised the following formula:

$$HP = 0.006\ H\ (0.001\ D + 0.367)\ (D - 4)^2$$

where HP is the capacity of the stack in boiler horsepower, H is the height of the stack in feet, and D is the diameter of the stack in inches.

This formula applies to stacks at sea level, and for higher altitudes the dimensions must be corrected as follows:

$$\frac{D}{D_0} = 1.0 + 0.017h \quad \text{and} \quad Log\ \frac{H}{H_0} = 0.0332h$$

where D and H are the dimensions of the stack at the given altitude, D_0 and H_0 are the dimensions at sea level, and h is the elevation in thousands of feet above sea level.

I have found that these formulas give results which check very well with the values given in the "Handbook," and I have used them to determine sizes beyond the limits of the tables.

WILLARD A. THOMAS.
Los Angeles, Cal.

More Convenient Observation of Blowoff Leakage

Having read the question and answer regarding more convenient observation of blowoff leakage, on page 683 of the April 27 issue, I think it might be interesting to mention another method that I have seen used with success.

This is to install an ordinary recording thermometer in the blowoff line. The temperature record will not only be an accurate indication of any leakage through the blowoff valves, but will also show when blowing down takes place.

New York City. G. A. BINZ.

[Such an installation was described on page 8 of the Jan. 7, 1919, issue of *Power*, and the chart obtained was illustrated. This chart gave the time and duration of the blowdown and also showed that the pen returned to its normal position, indicating that the blowoff valve was tight.—Editor.]

Superheating With Reciprocating Engines

Generally speaking, the reciprocating engine will be benefited as much by superheating as the steam turbine will. The saving to be expected by superheating is dependent on the amount of cylinder condensation that would occur in the same engine if no superheat were used. Evidently, the greater this condensation, the larger is the saving possible.

When steam is superheated 200 or even 250 deg. F., it can be exposed to the cooling action of the steam chest and cylinder walls without condensation, and has 30 to 40 deg. greater specific volume than saturated steam of the same pressure. For example, 1 lb. of water at 170 lb. pressure absolute produces 2.68 cu.ft. of saturated steam at 368 deg. F. temperature. After passing through the superheater and gaining 200 deg. superheat, the volume will have been increased to 3.54 cu.ft. A part of this increased specific volume is lost before the expansion of the steam in the cylinder takes place on account of the cooling action of the cylinder head, piston and cylinder walls. While the superheat in the steam entering the cylinder may be 200 to 250 deg., the superheat of the steam in the cylinder at the moment of cutoff is considerably less. The elimination of condensation losses together with the increased volume of the steam, effects substantial savings in the steam consumption and in the fuel consumption when compared with saturated steam operation under the same conditions.

The opinion has frequently been advanced that the mean effective pressure in cylinders using superheated steam is altered from that existing when saturated steam is used, the initial pressure, the point of cutoff and piston speed, of course, being assumed as the same in each case. Theoretical considerations would indicate that a lower mean effective pressure with superheated steam is obtained, and this conclusion would be based upon the knowledge that the expansion curve of superheated steam falls more rapidly than with saturated steam. In practice, however, with highly superheated steam a mean effective pressure at least equal to that with saturated steam is obtained and an explanation for this is easily made clear. For example: in simple noncondensing engines the back pressure line of an indicator diagram is decidedly lower with superheated steam than with saturated steam, a condition to be expected because the steam exhausted contains less moisture. It is, therefore, lighter than saturated steam, and flows through the exhaust passages with less resistance. C. D. Young, before the American Society of Mechanical Engineers in December, 1912, gave evidence of this fact.

In the case of multi-expansion reciprocating engines the diagrams taken from the low-pressure, and, in the case of triple engines, from the intermediate-pressure cylinder, show that a higher m.e.p. is obtained with superheated steam. In the high-pressure cylinder of multi-expansion engines it is generally true that the cutoff should be increased if the power output of the engine is to be maintained.

But our consideration of the possibility of increased engine power due to superheating must not stop here. Consider a saturated-steam plant in which the boilers are operating at their full capacity to supply the steam demanded by the prime movers. Take this same plant and superheat it—the decrease in steam consumption per horsepower-hour will result in a reserve boiler capacity which will either make possible the operation of the boilers at lower rating or furnish the additional steam necessary to meet an overload on the prime mover. In other words, superheating makes it possible to increase the power which the prime mover may develop over what it could produce with saturated steam.

In new installations the use of superheated steam permits the use of engines having larger cylinder diameters and operated with shorter cutoffs. Because cylinder condensation is eliminated, the gain in economy that is produced by the more effective expansion of the steam is realized.

Experiments have shown that the degree of superheat necessary to prevent cylinder condensation varies as a general rule with the ratio of expansion. In American practice the steam temperatures ordinarily recommended are up to 500 deg. F. for Corliss and slide-valve engines and up to 650 or 700 deg. F. for piston and poppet-valve engines.

The gain from decreased steam consumption due to superheated steam is ordinarily expressed in percentage. This gain will vary in various types of engines with the different superheat temperatures used. For example, with 150 deg. superheat the following gains are produced: In simple engines 22-24 per cent; compound engines 16-19 per cent; triple-expansion engines 14-16 per cent; uniflow engines 10-12 per cent. It is, however, an assured fact, and a strong argument for the more egneral adoption of high-degree superheat, that only engines designed for and using high degrees of superheat can successfully compete in economy in the power generation field.

It is often necessary, particularly with old boilers, to reduce the operating pressure. This condition results in a loss in plant capacity. Superheating such boilers will enable them to meet the power demands of the plant at the reduced pressure just as well as the boilers did before the pressure was reduced. Furthermore, superheating in the majority of cases will provide an additional reserve power over that of the plant before the pressure was reduced.

The installation of superheaters materially lowers the plant cost. Where it is used, a smaller amount of boiler horsepower is needed to deliver the same power. Roughly speaking, six boilers equipped with superheaters, furnishing 150 deg. of superheat, will carry the same power load as seven boilers delivering saturated steam. By reason of this, smaller feed pumps, smaller stacks, smaller coal-handling apparatus and less coal-storage space are sufficient for the demands.

Piping can be reduced in size, because higher steam velocities with superheated steam are possible. This reduction in pipe size will effect a saving not only in the pipe line, but also in valves, fittings and covering.

In the turbine superheated steam will allow the use of a conductor of a smaller size than if saturated steam were used. Consequently, smaller circulating water pumps, hotwell and vacuum pumps can be used and minor apparatus such as steam separators often can be dispensed with. These items materially reduce the initial plant cost.

When superheating is correctly applied to the individual conditions in a specific plant, it is the one means which will show an improvement in power-plant operation in at least one and probably all parts of the plant where steam is used.

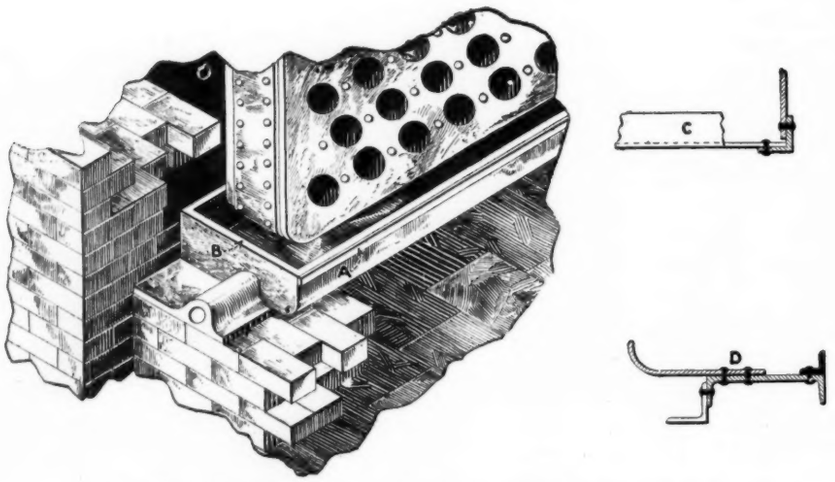
All the more astonishing, therefore, becomes the fact that in spite of all these practical advantages, only about 15 per cent of the steam horsepower of this country is developed from superheated steam. Furthermore, this percentage represents not more than perhaps 5 per cent of all the steam power plants, indicating that only plants of larger capacity, inherently more economical than the vast majority of stationary plants, use superheat.

Is it logical that comparatively few plants having high evaporation rates and low steam consumption, should be the ones to benefit by superheat, while 85 per cent of the nation's steam power uses fuel extravagantly? Because this condition is not consistent, the opportunity and the means to conserve fuel are available and the necessity is urgent. A. RAYMOND.

New York City.

Boiler Water-Leg Drip Pan

In stoker-fired boilers where the furnace extends forward of the front water leg and the boilers are of the horizontal water-tube type, considerable damage is done to the special arch and furnace tile, also to the stoker mechanism, by the drip of water, principally from the handhole plates.



APPLICATION OF DRIP PAN TO BOILER WATER LEG

The illustration shows a design of pan used for eight 425-hp. boilers, that has eliminated this trouble. The pan is cast in one piece and is of such dimensions as to extend the full length of the water leg and wide enough to extend 2 in. past the rear sheet to catch the drip at the expanded joint of the tubes; the front is curved up to meet the doors, and a ¼-in. projecting strip is provided for a joint *A*.

The side sheets of the front, which carry the door hinges, are fitted to the top edge of the pan *B*; an extension is provided for the support on the side walls, and this carries a 3½-in. diameter boss tapped for a 1½-in. pipe into the bottom of the pan; the end of this boss is flush with the side walls and is piped to the sewer.

This pipe is large enough to carry a flood of water such as occurs when cleaning out or when the pressure is released on all the handhole gaskets at once, as when a boiler is taken off the line. When the boiler is in service, the temperature at this point is such as to evaporate all minor leaks if the pan is tight.

The sketch *C* shows the usual method of providing for this leak where the drip pan is made up of channels and angles and forms a part of the door frame. Bolts are generally used to permit adjustment of the parts in erecting, and the water leaks through the bolt holes and also through the side-sheet joint, which is below the bottom of the water leg.

The cast-iron pan has lugs projecting from the bottom to carry the stoker cover angles; these dispense with the angle iron *D*. A. M. STILES.

St. Louis, Mo.

Where the Ammonia Charge Goes

In the April 20 issue of *Power*, J. E. Porter makes the statement that, "it is impossible to operate a plant and not lose some ammonia." While it is true that much ammonia is lost in both compression and absorption system plants, it is nevertheless possible to operate without the loss of ammonia by using a closed system and by sweating all joints. The writer is familiar with a number of installations where leakage is practically if not absolutely zero. They have operated on the same charge of ammonia without any replenishment whatsoever, and the chances are that they will continue for many more years on the same charge because the joints actually become tighter or less liable to leak with age. There are no reciprocating rods to pack, therefore there can be no leakage from that source.

Inasmuch as the joints in these installations are not sweated, and yet there is no evidence of leakage, it is plain that with commercially perfect joints (which can be made) there is no excuse for leakage. The only leak possibility would then lie in the safety valve, which might be lifted owing to excessive pressure, as sometimes happens where operators are careless. N. G. NEAR.

Brooklyn, N. Y.

Packing Valve Stems Under Pressure

On page 476 of the March 23 issue of *Power* Mr. Noble gives advice about how to pack valve stems under pressure. I believe that his suggestions could be worked out (if a person wants to court danger) on some kinds of valves, but not in the case to which I originally referred.

This valve was of cast iron, the bonnet was a flat plate with a U-shaped yoke, threaded to receive the valve stem. The packing was put in an annular space in the plate, where the stem went through it, and was held in place by a gland, tightened down with two stud bolts and nuts. I have found that kind of valve to be quite mean enough to pack, even when cold, in case you do not happen to have exactly the proper size of packing. GUSTAV SWENSON.

Rockford, Ill.

INQUIRIES OF GENERAL INTEREST

Live-Steam Coils for Oil-Storage Tanks—What is the objection to heating fuel oil in a storage tank with a pipe coil supplied with live steam? S. S. D.

The objection raised against the use of live-steam heating coils is that the temperature of the oil might be raised above the flash point and thereby liberate inflammable vapor.

Cleaning Water Jacket of Gas Engine—What solution can be used for cleaning the scale from the water jacket of a gas engine? R. M.

The scale usually consists of lime deposited out of the circulating water and can be removed by a solution of one part commercial muriatic acid and four parts of water. As soon as the solution has done its work, the water jacket should be thoroughly washed out with clean water to prevent unnecessary corrosion.

Loosening Piston Rod from Crosshead—How can the tapered end of an engine piston rod be started out of the crosshead? R. G.

Place the engine on the head-end center, remove the cotter and replace it by a cotter or piece of steel about one-eighth inch less in width than the clear space through the cotter way. Then detach the eccentric rod and, with the steam valve closed on the head end and open on the crank end, admit steam to the crank end of the cylinder. If the piston rod is not immediately released from the crosshead, clean the parts thoroughly and make another trial after leaving the joint moistened with kerosene for a few hours.

Cylinder Oils for Compound Engines—Are different kinds of cylinder lubricating oils necessary for use in the high- and low-pressure cylinders of a compound engine? R. C. N.

For obtaining good lubrication it is sometimes necessary to use different grades of oil. The drop of pressure in the high-pressure cylinder causes condensation and the supply of steam to the low-pressure cylinder will be wet, with a tendency to wash the film of oil off the surface of the cylinder and make lubrication more difficult. The oil used for the low-pressure cylinder should be of a quality that will readily combine with moisture and cling to the cylinder walls, and the oil obtainable for that purpose may not be suitable for the high-pressure cylinder.

Front and Back End and Forward Stroke—Which is the front and which is the back end of an engine cylinder and from which end is the forward stroke? C. R.

In stationary-engine practice the crank end is called the front end and the opposite end, commonly called the head end, is the back end. The forward stroke is toward the front; that is to say, it is the stroke from the back or head end toward the front or crank end. The distinction is readily fixed in mind by referring to the fact that, in an engine with a trunk piston, pressure for development of power is exerted on the piston only during its forward stroke, that is, when the piston moves from the back toward the front end of the cylinder. In locomotive practice the end of the cylinder which is in advance when the locomotive moves forward is designated the front end, and therefore the nomenclature is the reverse of that employed in stationary practice.

Ratio of Expansion—What is meant by the ratio of expansion in an engine? W. L. S.

In the operation of a steam engine, the ratio of expansion is the number of times the steam is expanded after cutoff occurs. If there is three cubic feet of steam present at cutoff and this is expanded to nine cubic feet, or three times the volume, the ratio of expansion is 3. The approximate ratio of expansion is the reciprocal of the fraction of stroke at which cutoff occurs. Thus, if cutoff occurs at ⅓ stroke, the approximate ratio of expansion is 3. But the actual volume at cutoff and after expansion includes the clearance volume at one end of the cylinder and must be included to find the actual ratio of expansion. Thus, if the clearance is 5 per cent of the piston displacement, and cutoff occurs at 0.33 of the stroke, the actual ratio of expansion would be

$$\frac{1 + 0.05}{0.33 + 0.05} = 2.76$$

Evaporation Required per Boiler Horsepower—How many pounds of water fed at the temperature of 160 deg. F. must be evaporated per hour into steam at 140 lb. gage pressure to make one boiler hoursepower? R. N. B.

The commonly recognized boiler horsepower consists in the transfer of the amount of heat required to evaporate 34½ lb. of water per hour, from and at 212 deg. F. The standard boiler horsepower therefore is equivalent to the transfer of the latent heat of evaporation to 34½ lb. of water per hour, or 970.4 B.t.u. × 34½ = 33,478.8 B.t.u. per hour. When the feed water is at the temperature of 160 deg. F., it contains 160 — 32 = 128 B.t.u. above 32 deg F., and as a pound of dry saturated steam at the pressure of 140 lb. gage, or 155 lb. absolute, contains 1,194 B.t.u. above 32 deg. F., each pound of feed water, for conversion into dry saturated steam, requires 1,194 — 128 = 1,066 B.t.u., and under these conditions it is necessary to evaporate 33,478.8 ÷ 1,066 = 31.4 lb. of water per hour for the evaporation to be equivalent to one boiler horspower.

Reducing Speed of Corliss Engine.—How can the speed of a Corliss engine be reduced from 75 to 60 r.p.m. if the weight on the governor has been set over as far as it will go for reducing the speed? E. B.

Ascertain what speed of engine is obtained when the weight for adjusting the speed is set at about the middle of its adjustment. Then, to retain the same speed of the governor with regulation at 60 r.p.m. of the engine, replace the receiving pulley on the governor by one whose diameter is equal to the diameter of the present governor pulley multiplied by 60 and divided by the ascertained r.p.m. of the engine; or replace the governor driving pulley on the engine shaft by one whose diameter will equal that of the present pulley multiplied by the ascertained r.p.m. and divided by 60. The exact change of speed will not be obtained on account of a small error due to neglecting consideration of thickness of the governor belt, but the deviation will be so little from the desired speed that it can be corrected by changing the position of the speed-adjusting weight.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. —Editor.]

The Prime Movers Committee Report on Steam Turbines

Salient Features of the Report of the Prime Movers Committee, National Electric Light Association, Pasadena, California

A RECORD of the units that have been manufactured since the last report indicates that 30,000-kw. 1,800 r.p.m. 60-cycle, and 35,000-kw. 1,500 r.p.m. 25-cycle, can be considered for the present as the maximum standard size of single-shaft single-barrel unit for large installations.

During the last year a considerable amount of information has been obtained from the operation of the smaller machines, and a period of adjustment and improvement in both design and construction, following the experience that has been gained, would seem to be imperative if these large-sized machines are to be brought to a requisite degree of reliability and operating efficiency.

The records of operation of single-shaft units have not by any means been satisfactory. Since the last report several addition wheel failures have occurred to units of this type and on sizes ranging from 5,000 to 30,000-kw. capacity.

Changes in Design of Large Turbines

The General Electric Co. has made a number of marked changes in the design of its large-sized turbines, the principal changes being the stiffening of the center bearing and modifications in the design of turbine discs, buckets, diaphragms and packing.

The changes in the turbine discs consist of a thickening of the disc in an attempt to reduce the possibility of injurious vibration; elimination of the weight-balancing holes, and the change in the number and location of steam equalizing holes so as to move them well in from the rim; and changing from an even number to an odd number of holes with rounded and polished edges at the wheel surface.

The changes made in the buckets, particularly in the last stages, consist of the addition of a reinforced section, carrying it nearly to the center of the bucket so as to stiffen the construction materially. In addition, the very long buckets are reinforced by the use of a bracing strip to minimize vibration which might occur.

The changes to the diaphragms consist in replacing some of the cast-iron sections by cast-steel construction where stresses indicate this to be necessary. Additional clearance space around the diaphragm is also provided with the idea of allowing for the removal of a large part of the condensed water, which has contributed to serious erosion of the blading in certain stages.

A radical departure has been made in the type of diaphragm packing. The new type differs from the earlier construction in that the stationary, inwardly projecting short teeth of the labyrinth have been changed to much longer teeth which are mounted on the revolving element. It is claimed that this improvement makes it practically impossible, when properly installed, for rubbing to distort the shaft due to the generation of heat at the point of contact.

Causes of Wheel Failures

An analysis of the causes of the serious wheel failures has resulted in the accumulation of sufficient data to indicate that the trouble has been due in the past to a vibration of the wheel structure. This vibration, which has been described as a fluttering of the web of the wheels, in combination with the high working stresses of the material, gives rise to the formation of fatigue cracks. These cracks, which occur not only in the wheel but also in the bucket, when allowed to continue, result in a complete rupture. This action was accentuated in the discs where sharp tool marks or rough surfaces are present, or where holes for weight or steam-balancing purposes are drilled in the wheel. There is, however, considerable investigation still necessary in connection with the subject of vibration of wheel before all the facts can be known and a proper design be forthcoming that will eliminate danger from this source of trouble. The manufacturer is devoting considerable attention to this subject, and it is believed that some definite information will soon be available.

No marked changes have been introduced during the past year by the Westinghouse Electric and Manufacturing Co. in the design of its single-cylinder units up to 30,000-kw. rating, although a number of minor improvements have been made in the details of design and construction, with a view to increasing the reliability and efficiency of its units. To meet the demand for larger capacities than 30,000 kw. the company has standardized on combinations of single-cylinder units of 20,000 to 22,000-kw. maximum rating in tandem, cross-compound and triple-cylinder arrangements.

While the combination of compound turbo-generators seems to be increasing in favor, and while test results indicate a higher thermal efficiency for such a combination as compared with single units of the same aggregate capacity, sufficient data are not at hand to show conclusively whether the practical operation of units bears out the theoretical advantages which are claimed.

Starting of Large Turbines

One of the most important considerations in connection with the operation of large turbines of 20,000-kw. capacity and over is the necessity for extreme care in the starting and loading of units, especially when the machines have been idle for a period long enough to lower materially the temperature at which the various parts are normally operated. With the introduction of steam to a cold unit there is at once set up a difference in temperature between the various elements, which, unless a careful procedure is followed, may result in unequal expansions, affecting the shafts, blading, diaphragms, packing or casing joints. In some cases on record, sudden and unequal expansion has caused deformation which has resulted in permanent distortions to casings and bearings, materially affecting the subsequent operation of the machine.

A survey of the operating methods in use in a number of companies indicates that there is considerable variance in the practice which is followed in starting large turbines. The time required to heat a cold unit to the temperature where full load can be carried will, naturally, vary with the type, size and class of turbine. No hard and fast rule of procedure can be definitely laid down, except that in all cases no large unit can be safely loaded which has not been given sufficient time to allow all parts of the unit to reach evenly and gradually the individual normal operating temperatures corresponding to load conditions.

Data secured from operating companies show that the procedure generally followed consists in establishing a partial vacuum of from 15 to 20 in. prior to starting the unit, and maintaining this during the period of warming.

In warming the turbine and bringing it to speed, the first operation of introducing steam should admit a sufficient volume to start the rotor turning immediately. Steam admission should then be so regulated that the unit will continue turning at a speed not exceeding 10 per cent of the normal operating speed until the warming process is completed. Additional steam should then be admitted gradually to the turbine to bring it up to full speed.

While the time taken for this operation varies among different operating companies, the safe minimum time allowed, based on best operating experience, is given as twenty minutes for units of 20,000-kw. capacity, and thirty minutes for units of 30,000 kilowatts.

In applying load to the unit, the rule observed for safe operation by a number of operating companies is to increase the load on the unit at a rate not exceeding 1,000 kw. per

minute for units of the size mentioned. While there is considerable variation from the procedure noted, the reason is that in many cases certain local requirements or special plant conditions govern. It will be noted, therefore, that in following the foregoing practice, the minimum time for heating and loading large units will vary from forty minutes for a 20,000-kw. turbine to sixty minutes for a 30,000-kw. unit, or a rate of two minutes for each 1,000-kw. turbine capacity.

These figures do not refer to machines which have not been idle long enough to cool off perceptibly, in which case shorter length of time can be taken, depending on the individual circumstance.

Emergency Governors

Attention has recently been called to the operation of turbine emergency governors. While a few companies have been operating machines for some time on which the emergency governor, after operating, became again operative at approximately 2 per cent above normal speed, most of the turbines now in service are equipped with emergency governors so designed and adjusted that it is necessary to drop the machine speed below normal to latch the emergency again after it has operated. In certain cases of operating trouble it is necessary to have the emergency governor springs so adjusted that they will operate over the reduced range and avoid the necessity of disconnecting the generator from the system to reduce the speed of the unit below normal.

Personnel of the Prime Movers Committee

N. A. Carle, Chairman, Chief Engineer, Public Service Electric Co., Newark, N. J.

H. P. Liversidge, Vice Chairman, Assistant Chief Engineer, Philadelphia Electric Co. Chairman, Turbine Committee.

H. R. Wakeman, Vice Chairman, Portland Light and Power Co., representing Northwestern Electric Light and Power Association, Portland, Ore.

R. J. C. Wood, Vice Chairman, Superintendent of Generation, Southern California Edison Co., Los Angeles, Cal.

C. M. Allen, Worcester Polytechnic Institute, Worcester, Mass.

John Anderson, Chief Engineer, Milwaukee Light, Heat and Traction Co., Milwaukee, Wis.

A. D. Bailey, Assistant Chief Engineer, Commonwealth Edison Co., Chicago, Ill.

E. J. Billings, Engineer, Henry L. Doherty & Co., New York City.

H. B. Brydon, Engineer, H. M. Byllesby Co., Chicago.

F. S. Clark, Engineer, Stone & Webster, Boston.

C. W. De Forest, Manager, Electric Department, Union Gas and Electric Co., Cincinnati, Ohio.

R. D. De Wolf, Mechanical Engineer, Rochester Railway and Lighting Co., Rochester, N. Y.

R. E. Dillon, Assistant Superintendent, Generating Department, Edison Electric Illuminating Co., Boston, Mass.

H. F. Eddy, Consumers Power Co., Jackson, Mich.

Louis Elliott, Engineer, Electric Bond and Share Co., New York City.

W. W. Erwin, Chief Engineer, New York Edison Co., New York City.

S. B. Flagg, Fuel Expert, Electric Bond and Share Co., New York City.

J. M. Graves, Superintendent Power Stations, Duquesne Light Co., Pittsburgh, Pa.

C. F. Hirshfeld, Research Engineer, Detroit Edison Co., Detroit, Mich.

John Hunter, Standard Shipbuilding Co., Shooter's Island, N. J.

J. P. Jollyman, Engineer, Electrical Construction, Pacific Gas and Electric Co., San Francisco, Cal.

J. B. Klumpp, Inspecting Engineer, United Gas Improvement Co., Philadelphia, Pa.

John W. Koontz, Jr., Electrical Engineer, Great Western Power Co., San Francisco, Cal.

A. W. Morgan, Results Engineer, Denver Gas and Electric Co., Denver, Col.

A. A. Potter, Dean, Division of Engineering, Kansas State Agricultural College.

E. B. Ricketts, Assistant to Chief Operating Engineer, New York Edison Co.

G. W. Saathoff, Electrical Engineer, The Acme Power Co., Toledo, Ohio.

H. H. Schoolfield, Engineer, Pacific Power and Light Co.

E. D. Searing, Portland Railway, Light and Power Co., Portland, Ore.

S. S. Svenningson, Engineer, Shawinigan Light and Power Co., Montreal, Canada.

E. H. Tenny, Assistant Chief Engineer of Power Plants, Union Electric Light and Power Co., St. Louis, Mo.

R. L. Thomas, Electrical Engineer, Pennsylvania Water and Power Co., Baltimore, Md.

O. G. Thurlow, Chief Engineer, Alabama Power Co., Birmingham, Ala.

W. H. Trenner, Chief Engineer, Idaho Power Co., Boise, Idaho.

J. F. Vaughn, Consulting Engineer, Boston, Mass.

J. A. Walls, Vice President and Chief Engineer, Pennsylvania Water and Power Co.

John Wolff, Mechanical Engineer, Cleveland Electric Illuminating Co., Cleveland, Ohio.

H. P. Wood, Operating Superintendent, Edison Electric Illuminating Co., Brooklyn, N. Y.

Geographical Distribution of Coal and Power Activities*

It is one of the great problems of today to determine the location of the vast sources of fuel and power and their relation to the present and near future demands. Bituminous coal, forming as it does the major portion of our fuel supply for industrial purposes, is the only fuel which will be considered in this discussion. The distribution of coal reserves is the best evidence of what will necessarily be our resource for extended periods in the future. Table I is from data developed by M. R. Campbell, of the United States Geological Survey, and reported at the International Geological Conference in Toronto in 1912. In this table the states have been divided into groups and the probable reserves and probable life of these reserves are shown for each group. It is interesting to note the relation between the amount of reserve and probable life in the northeastern fields of Pennsylvania and those in the mountain territory of the West. Naturally, these figures are only approximate, but they afford a significant fact in respect to the ultimate location of our energy reserves.

A study of data and charts showing the distribution of water-power resources indicates that the bulk of these also is to be found principally in the West. It is not to be expected from the figures, however, that the West is to dominate industrially in the immediate future, for a period of centuries is involved here, not a few years.

In connection with the distribution of coal consumption the current production and current consumption are shown in Table II, where the states are arranged in the same groups as in Table I. A study of this table shows that for any group of states the production and consumption are of approximately the same magnitude. In other words, the actual statistics show, what might be expected, that coal is used as near the place of production as possible. Another interesting fact shown by the table is that New England, New York, Pennsylvania, New Jersey and the North Central states together consume about 68 per cent of the total coal consumption of the country, which gives some indication of the enormous concentration of the demand for fuel in this comparatively restricted area.

A study of the water-power resources and of the demands for power brings out the fact that the former are principally in the western part of the country, while the demand for power, like that for fuel, is concentrated very largely in the northeastern corner of the United States. A somewhat similar contrast will be found if we compare the present current use of coal and the coal reserves as estimated by the geologists. In other words, power and

*Abstract of an article by R. S. McBride, in *Coal Age*.

coal are not, as some have claimed, supplementary throughout the country, with coal available in the East and power available in the West. The facts are quite to the contrary, for the West includes a large majority of the resources of both coal and water power.

It seems evident, then, from a study of these figures that the western part of the country is bound in the future to dominate the industries of the country since only there will be found the fundamental requirements of industry—an adequate supply of fuel and power. As stated before,

TABLE I. BITUMINOUS-COAL RESERVE

(Data from Marius R. Campbell, U. S. Geological Survey, as reported to International Geological Congress, Toronto, 1912)

District	Reserve — Billions of Tons	Reserve — Per Cent of Total	Life at Present Rate of Use (Centuries)
New England	None	0	0
New York, Pennsylvania, New Jersey	102.2	5	6
South Atlantic	166.3	7	15
North Atlantic	327.1	15	20
South Central	196.5	9	30
Northwestern	129.9	6	60
Southwestern	58.5	3	60
Mountain	1,178.5	52	330
West Coast	58.9	3	140
Total or average	2,217.9	100	Aver. 40

TABLE II. DISTRIBUTION BY DISTRICTS OF COAL
Production and Use

(Production based on U. S. Geological Survey report. Consumption estimated on assumption (1) of total use equal to total production and (2) of total use, including railroads and bunker fuel in same proportion as use for other purposes besides railway and bunker.)

District	Produced (1918) Millions of Tons	Produced (1918) Per Cent of Total	Estimated Consumption (On 1917 Basis) Millions of Tons	Estimated Consumption (On 1917 Basis) Per Cent of Total
New England	0	0	28.9	5.0
New York, Pennsylvania, New Jersey	178.5	30.9	168.9	29.1
South Atlantic	104.7	18.0	46.4	8.0
North Central	167.3	28.9	197.9	34.2
South Central	57.6	10.0	37.5	6.5
Northwestern	22.2	3.8	59.8	10.3
Southwestern	9.3	1.6	11.1	1.9
Mountain	35.4	6.1	23.7	4.1
West Coast	4.1	0.7	4.9	0.9
Total	579.1	100.0	579.1	100.0

however, this is a situation which has no immediate interest. If the figures given in Table I are at all accurate, the life of the Eastern coal field is from six to twenty centuries at the present rate of production. Even if this production should be very largely increased, it is obvious that the life of these fields would still be a matter of centuries rather than of years.

American Institute of Electrical Engineers Elects Officers

At the annual business meeting of the American Institute of Electrical Engineers, held in New York, May 21, the report of the Committee of Tellers on the election of officers for the administrative year beginning Aug. 1 was presented and the following were declared elected: President, A. W. Berresford, Milwaukee; vice-presidents, E. H. Martindale, Cleveland, Charles Robbins, Pittsburgh, Charles S. Ruffner, New York, C. E. Magnusson, Seattle, C. S. McDowell, U. S. Navy, and L. T. Robinson, Schenectady; managers, E. B. Craft, New York, H. B. Smith, Worcester, and James F. Lincoln, Cleveland; treasurer, George A. Hamilton, Elizabeth, N. J. (re-elected).

The foregoing, together with the following hold-over officers, will constitute the Board of Directors for the next administrative year: Calvert Townley, New York; Comfort A. Adams, New York; Walter A. Hall, Atlantic, Mass.; William A. Del Mar, New York; Wilfred Sykes, Pittsburgh; Walter I. Slichter, New York; G. Faccioli, Pittsfield; Frank D. Newbury, Pittsburgh; L. E. Imlay, Niagara Falls; F. F. Fowle, Chicago; L. F. Morehouse, New York.

T. L. Hutchinson was re-elected secretary of the institute for the coming year.

*Abstract of an article by R. S. McBride, in *Coal Age*.

Carl G. Barth Honored by the Taylor Society

Carl G. Barth, pioneer in the machine-building industry, has been elected an honorary member of the Taylor Society, the national organization for the promotion of science in management. Only two other men have been honored by the society, these being Frederick W. Taylor and Henri Le Chatelier, the prominent engineer who developed scientific management in France.

Mr. Barth, after completing engineering studies in his native land, Norway, came to this country in 1881 and was employed as a draftsman by William Sellers & Co. From 1895 to 1899 he was engaged in engineering work in St. Louis. He became associated with Mr. Taylor at Bethlehem, Pa., with whom he worked on the historic foundations of scientific management. Under Mr. Taylor's direction he conducted experimental work on metal-cutting tools and applications of slide rules in the plants of the Link-Belt Co. and the Tabor Manufacturing Co.

Mr. Barth's work on the fundamental formulas in cutting metals has received world-wide recognition as one of the most important contributions to machine development.

Seven proposals were received by Acting Secretary Roosevelt under the opening of bids for coal for the Navy, on May 18. These aggregate a total of 319,000 tons of bituminous coal and 3,700 tons of anthracite.

The annual requirements of the Navy are 2,174,800 tons of bituminous coal and 38,215 tons of anthracite. At the principal point of delivery, Hampton Roads, Va., there was offered 185,000 tons of the 1,200,000 tons called for. The prices per gross ton quoted in the bids range from $4.20 to $4.816 f.o.b. mines. The base price at present being paid by the Navy under commandeering orders for coal taken at Hampton Roads, including allowance for the advancement in wages, is about $3.70 per gross ton.

WANTED: A PRACTICAL MAN

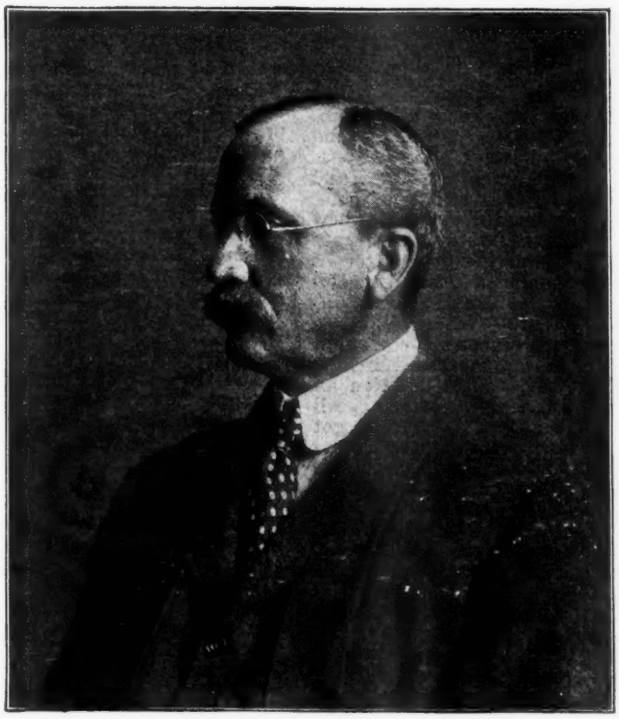
From Engineering and Mining Journal

Edison Medal Presented to William LeRoy Emmet

AT THE annual meeting of the American Institute of Electrical Engineers in the auditorium of the Engineering Societies Building, New York, on May 21, the annual presentation of the Edison Medal was made to William LeRoy Emmet "For Inventions and Developments of Electrical Apparatus and Prime Movers."

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Thomas A. Edison, and is awarded annually by a committee consisting of twenty-four members of the American Institute of Electrical Engineers, "for meritorious achievement in electrical science, electrical engineering, or the electrical arts."

The first medal was presented in 1909 and since that time ten medals have been awarded.



WILLIAM LeROY EMMET

The ceremony was opened by Carl Hering, chairman of the Edison Medal Committee, who described the medal and gave a brief history of its origin.

H. W. Buck, past president of the American Institute of Electrical Engineers, followed Mr. Hering and related the achievements of Mr. Emmet. He said in part:

It has been my privilege for a great many years to have known Mr. Emmet personally and later on in life to have been intimately associated with him in his professional activities. One of my earliest recollections of Mr. Emmet is as dressed in the uniform of an ensign in the Navy.

In 1892 Mr. Emmet was transferred from the Chicago office to the New York office of the Edison General Electric Company and started in there as engineer of the Foreign Department. From that position he was transferred to be engineer of the lighting department, and his real professional work, as I think we understand it, began at that time.

The lighting industry was expanding by leaps and bounds. It had been proved a commercial success and plants were being established all over the country. A great many great engineering problems were experienced and all kinds of difficulties due to the rapid growth and the newness of the art. Mr. Emmet tackled these problems with great vigor, with the result that in the following year some of his important work was carried on.

The lighting plants at that time were growing very fast and had run into very serious difficulty, due to the enormous amount and cost of the copper which was necessary, due to the rapidly expanding growth of the Edison system. Of course, at 220 volts you cannot go very far without an enormous expenditure in copper. One solution which was being offered was the construction of a half dozen different power stations around the city, which generated direct current at certain centers and to distribute it for limited distance. Emmet did not believe in this and took hold of the problem and saw that the central-station principle was the thing to adopt, and this, combined with alternating current underground cable distribution, with the establishment of rotary convertor substations throughout the metropolitan districts in our various cities, was the proper thing to do, and he pushed that plan forward with great vigor and convinced the executives of many of the great lighting systems throughout the country that this was the way to meet the problem, with the result, from that day to this, that that has been the method of distributing Edison current throughout our cities.

He worked at this time on the problem of the load transformers, which became necessary in the various systems

devised methods of ventilation and other systems, and invented, designed and installed the first of our air blast transformers which were put in at that time, and which were quite radically new. He also worked on methods of cooling and ventilating both transformers and generators.

Then a very serious difficulty was experienced which looked as if it was going to block absolutely the further development of electrical distribution of power, and that was the difficulty in controlling the electric circuits which were then becoming very large, both in power and current. Emmet tackled this problem, analyzed its difficulties and started in an extensive campaign to solve it.

The central stations of the country were powerless and could not control the circuits, and the only means of doing this was to kill the field in the generator. Emmet knew that was not the thing to do and took a most active part in the experiments made that year and the year after at Brooklyn and Niagara Falls, where almost every conceivable form of circuit-breaking device, representing the individual ideas of almost every man in the General Electric Company, was tested out. There were schemes for opening circuits, understand, under the action of compressed air, air blasts, sprays, and all sorts of devices, and in addition an ordinary jug of oil, by which the contact was broken. All of these devices were tested out, and they finally got around to the oil switch, through which was short circuited a five thousand kilowatt machine, under heavy inductive load, and the circuit opened several times. Nothing happened, and apparently there was an open circuit. The thing was tested out three or four times, and found to be all right, and the circuit opened again, and it was finally discovered that these very high powered inductive short circuits were being opened under oil, without the slightest commotion.

In connection with Mr. Emmet's work in the turbine, I think he was the first to point out to steam engineers the tremendous importance of high vacua in the operation of the turbine.

In 1913 he started some of the most important work he has ever undertaken, and that is the development of the mercury turbine, which he is now engaged upon. Mr. Emmet realized the difficulty of getting enormously high steam pressures and temperatures, so he devised an entirely new system of boiling mercury, which gives a temperature of approximately 700 deg. The mercury vapor at this temperature is then discharged into a mercury turbine and the condenser of the mercury turbine is the steam boiler, so that all the heat from the condenser of the mercury turbine is used for boiling the water, which, in turn, is discharged into a steam turbine, which operates in the usual way, so that with a certain amount of heat generated, you get the equivalent in steam operating the steam turbine, in addition, as practically free power, and you get all the power which the mercury turbine will generate. The result is a revolutionary saving and economy, in that you get thirty or forty or even more per cent of power from a given amount of coal consumed.

That experimental work is now in progress, and I understand that the results will be very soon applied commercially. If it is as successful as it looks, it will probably revolutionize all of the power plants in this country. I think we can all hope and believe that these experiments will be successful.

In conclusion I think that I represent the sentiments of all of the engineering fraternity when I say that we are very glad to have this opportunity to give this token to Mr. Emmet of our appreciation of his great work, and our appreciation of himself as an engineer.

President Calvert Townley of the A. I. E. E., following Mr. Buck's address, made the presentation of the medal, after which Mr. Emmet made the response. He said in part:

Mr. Buck spoke of something I did not want to talk about, because it is not an accomplished fact—that is, the mercury process. That is something I have done myself, and in which I am vitally interested, and expect to devote all the rest of my life to it if necessary, and allow nothing to interfere with it, because I believe it is a great thing. I will not attempt to describe the reasons, but we have already accomplished a lot in that respect.

Of course, mercury costs one dollar a pound, it is a deadly poison if it gets into the atmosphere, and a very large amount of it must be vaporized—for every pound of steam made, something like 8 lb. of mercury is vaporized, but as now developed that vaporization of mercury goes on in a whole system of apparatus which is all one piece, all welded from top to bottom into a single piece, practically, except where the back of the turbine goes through the shaft, and it has been tested to a pressure three or four or five times as great as that used, as we use a very low pressure, and it is developed in such a way that no possible application of heat in the furnace can overheat anything, and in fact, our experience for years with various devices has shown that the essentials, the things which would have been thought difficult about this process, are easy, and are not going to give us any trouble. We have had some trouble about expansion and certain strains, etc.

We are now making a commercial application of this thing and hope it may be brought to an actual commercial success in a very short space of time. It is a process applicable to everything wherever power is used—locomotives could be run by that method with a fuel consumption something like one-third of what they now use, and run without wasting the water; it could be made to condense its own steam as a steam automobile does.

My love has been for electricity, and my aims have been to develop the electric art. I have a confident belief in the practicability of doing things by the electrical art, and that is what I have been aiming at in doing these other things.

New Officers N. E. L. A.

At the convention of the National Electric Light Association, at Pasadena, Cal., May 21, the following were elected as officers for the ensuing year: President, Martin Insull; vice-presidents, M. R. Bump, F. W. Smith, W. H. Johnson and Franklin Griffith; treasurer, H. C. Abell.

An increase of approximately 20 per cent in the cost of labor and material, unexpected and unforeseeable construction difficulties and a change in the power-house plans are given by the Great Western Power Co. of California as reasons for a stock issue of $1,500,000 asked for in an application filed with the Railroad Commission. The company says that it will need the money raised through the proposed sale of its preferred stock to complete what is known as its Caribou plant.

Obituary

George E. Long, Jersey City, N. J., president of the Joseph Dixon Crucible Co., has retired after 43 years of active service.

Personals

Francis Juraschek has become associated with Hanff-Metzger, Inc., general advertising agents, New York. He has been placed at the head of the Technical Department.

D. Gleisan, manager, Industrial Bearings Division, Hyatt Roller Bearing Co., has appointed W. F. Myer to be directing transmission engineer. Mr. Myer will be responsible for the sale of Hyatt lineshaft roller bearings.

Society Affairs

The Philadelphia Section of the A. I. & S. E. E. will hold its annual outing at Brown's Mills-in-the-Pines June 5.

The Association of Iron and Steel Electrical Engineers has postponed the trip scheduled for the inspection of the Trumbull Steel Co., Warren, Ohio, on May 22, until sometime in June.

The American Society of Civil Engineers, Philadelphia Section, will meet at the Rensselaer Polytechnic Club on June 7. The subject of the meeting will be "The Relation of the Owner, Engineer and Contractor."

The Association of Iron and Steel Electrical Engineers, Pittsburgh Chapter, will meet on June 12. R. H. Keil, power engineer of the Jones & Laughlin Steel Co., will read a paper on "Current Limit Reactance."

The New Orleans Section, A.S.M.E., will meet at the Lafayette Theatre on June 4. W. M. White, chief engineer, hydraulic department of the Allis-Chalmers Co., will read a paper on "Installation of Large Turbo-Alternator at Niagara."

Cleveland Section, A.S.M.E., will meet on June 8. A number of local industrial plants will be inspected during the day. This will be followed by dinner at the University Club. Col. Edward A. Deeds, Dayton Ohio, and Mr. Cattell, of Philadelphia, will be the speakers.

The Central Geographic Section of the Pennsylvania Electric Association, State Branch of the N. E. L. A., will meet in the Penn Harris Hotel, Harrisburg, on June 4. W. J. Kline, of the American Heating Co., North Tonawnada, will deliver a paper on "Central Station Heating." The rest of the morning will be taken up by five-minute talks on subjects of interest to the members. In the afternoon H. R. Kern, auditor, Philadelphia Electric Co., will deliver an address on "Accounting and Operating Records."

COAL PRICES

Prices of steam coals both anthracite and bituminous, f.o.b. mines, unless otherwise stated, are as follows:

ALANTIC SEABOARD

Anthracite—Coals supplying New York, Philadelphia and Boston:

	Mine
Pea	$5.30@$5.75
Buckwheat	3.40@ 4.10
Rice	2.75@ 3.25
Barley	2.25@ 2.50
Boiler	2.50

Bituminous—Steam sizes supplying New York, Philadelphia and Boston:

Latrobe	$4.25@$4.50
Connellsville coal	4.25@ 4.50
Cambrias and Somersets	4.35@ 5.15
Clearfields	4.00@ 4.75
Pocahontas	6.50@ 7.00
New River	6.50@ 7.00

BUFFALO

Bituminous—Prices f.o.b. Buffalo:

Pittsburgh slack	$6.00
Mine-run	6.25
Lump	6.00@ 6.50
Youghiogheny	6.75

CLEVELAND

Bituminous—Prices f.o.b. mines:

No. 6 slack	$3.25@$4.00
No. 8 slack	4.25
No. 8—¾-in.	3.50@ 4.00
No. 6 mine-run	3.50@ 4.00
No. 8 mine-run	4.50
Pocahontas—Mine-run	3.25@ 4.00

ST. LOUIS

Anthracite—Probably not more than 20 per cent of the demand in this market can be supplied. Prices effective Apr. 1 were as follows:

	Williamson and Franklin Counties	Mt. Olive and Staunton	Standard
Mine-run	$2.65@2.80	$3.00@3.50	$3.75@4.25
Screenings	2.50@2.65	2.50@3.00	2.75@3.50
Lump		3.75@4.50	4.00@4.50

Williamson-Franklin rate to St. Louis is $1.10; Other rates 95c.

CHICAGO

Bituminous—Prices f.o.b. mines:

		Freight rate
Illinois		
Southern Illinois		
Franklin, Saline and Williamson Counties		Chicago
	Mine-Run $3.00@$3.10	$1.55
	Screenings 2.60@ 2.75	1.55
Central Illinois		
Springfield District		
	Mine-Run $2.75@$3.00	$1.32
	Screenings 2.50@ 2.60	1.32
Northern Illinois		
	Mine-Run $3.50@$3.75	$1.24
	Screenings 3.00@ 3.25	1.24
Indiana		
Clinton and Linton		
Fourth Vein		
	Mine-Run $2.75@$2.90	$1.27
	Screenings 2.50@ 2.65	1.27
Knox County Field		
Fifth Vein		
	Mine-Run $2.75@$2.90	$1.37
	Screenings 2.50@ 2.60	1.37
Brazil Bloke	$4.25@$4.50	$1.27

New Construction

PROPOSED WORK

Me., Fort Kent—The Fort Kent Electric Co. plans to construct a 33,000 volt transmission line to connect at Van Buren, with the Maine & New Brunswick Electric Light & Power Co., a distance of 43 miles.

Mass., Boston — Appleton & Stearns, Archts., 53 State St., will soon receive bids for the construction of a 3 story, 80 x 300 ft. sales and service station on Commonwealth Ave., for the J. W. Maguire Co., 745 Boylston St. A steam heating system will be installed in same. Total Estimated cost, $400,000.

Mass., Boston—The Bd. Educ., City Hall, will soon award the contract for the construction of a 2 story school addition on Charter St. An extension to the steam heating system will be installed in same. Total estimated cost, $350,000. C. H. Walker & Son, 71 Kilby St., Archts.

N. Y., Brooklyn—The Dept. of Charities, Municipal Bldg., New York City, will soon award the contract for making boiler repairs at the Kings County Hospital. Estimated cost, $8,000.

N. Y., Brooklyn—W. Small, 189 Montague St., is having plans prepared for the construction of a theatre on Grand Ave. A steam heating system will be installed in same. Total estimated cost, $500,000. Eugene De Rosa, 110 West 40th St., New York City, Archt. and Engr.

N. Y., Buffalo—Severn A. Anderson, Erie Co. Treas., City and County Hall, will soon award the contract for the installation of a steam turbine driven 35 kw. generator in the 65th armory here.

N. Y., Buffalo—The Niagara Machine & Tool Works., 633 Northland Ave., is in the market for one 150 kw. synchronous converter, or motor generator set, to convert 3 phase, 25 cycle, 2,000 volt a.c. to 230 volt d.c.

N. Y., Byron — The Genesee Light & Power Co. plans to construct an electric light and power plant here.

N. Y., Kings Park—The State Hospital Comn., Capitol, Albany, will receive bids until June 2 for the installation or heating and sanitary work, etc., in the building for acute patients, at the Kings Park State Hospital, here.

N. Y., Lockport—Dumville & Co. are in the market for a 3 hp. single phase, 60 cycle, 110 volt, 1,200 r.p.m. motor.

N. Y., Malone — The Malone Light & Power Co. is in the market for a 300 kw., 2,400 volt, 3 phase, 60 cycle a.c. generator, complete with exciter unit and direct connected to a pair of horizontal water wheels of 400 or 500 hp. capacity to operate under a 25 to 30 ft. working head. S. G. Hunter, Supt.

N. Y., New York—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., plans to install a reciprocating air compressor. Estimated cost, $60,000.

N. Y., New York—Marc Klaw, Commercial Trust Co. Bldg., B'way. and 41st St., is having plans prepared for the construction of a theatre on 45th St. between B'way. and 8th Ave. A steam heating system will be installed in same. Total estimated cost, $300,000. Eugene De Rosa, 118 West 4th St., Archt. and Engr.

N. Y., Ossining — Charles F. Rattigan, Supt. of Prisons, Capitol, Albany, received bids for furnishing and installing pumping machinery, etc., in the Sing Sing Prison, here, from F. N. Lewis, Hotel Charleton, Binghamton, $8,700; Suburban Eng. Co., 15 West 38th St., New York City, $8,976. Noted May 3.

N. Y., Rochester—The Eastman Kodak Co., 333 State St., plans to construct a 70 x 150 x 362 ft. machine shop, cost, $280,000 and a 98 x 98 x 146 ft. power house, cost $200,000.

N. Y., Schenectady—The Bd. of Contract and Supply will receive bids until June 9 for the installation of plumbing, heating and electrical work at the Pleasant Valley School, Forest Rd.

N. Y., Wellsville—George C. Ross, Chn. of the Bd. of Water & Light Comrs., has received bids for extensions to the electric light plant, here, from H. M. Cushing, 49 Roanoke Ave., Buffalo. The extensions include the delivery and installation of a turbine generator, condensor, circulating pumps and interconnected piping, $20,000; piping steam and water, $2,000; changing from 2 phase to 3 phase, 2,300 volts, $2,000; outside changes, $4,500; line extensions $5,000; gas engine repairs, $1,500.

N. J., Butler—The Borough is having plans prepared for the construction of a 1 story, 50 x 50 ft. municipal lighting plant. A heating boiler, two 100 kw. engines, auxiliary equipment, air compressor and steel tanks will be installed in same. Total estimated cost, from $50,000 to $60,000. Runyon & Carey, 845 Broad St., Newark, Engrs.

N. J., Sayreville—The Borough plans to construct a water supply system which will have a daily capacity of 250,000 gal. Plans include a steel tower tank to hold 200,000 gal. pumping units, 2 triple single acting pumps, engine house, etc. Waldo S. Coulter, 114 Liberty St., New York City, Engr.

N. J., South River — The Bd. of Pub. Wks., received bids for the construction of a turbine engine plant at the power house here, from the John R. Proctor Eng. Co., 74 Cortlandt St., $197,368; Equity Eng. Co., 30 Church St., $211,726; Leslie Stevens Co., 120 Bway., $214,900. All of New York City. Noted March 3.

N. J., Vineland—F. H. Bent, Archt., 142 West State St., will soon award the contract for the construction of a 2 story, 50 x 75 ft. storeroom and refrigerator plant. Machinery will be installed in same. Total estimated cost, $30,000. Noted May 18.

Pa., Johnstown — Dennison & Hirons, Archts. and Engrs., 475 5th Ave., New York City, will soon award the contract for the construction of a 12 story, 60 x 110 ft. bank and office building, for the United States Natl. Bank here. A steam heating system will be installed in same. Total estimated cost, $500,000.

Pa., Scranton—D. J. Bondy, 80 Wall St., New York City, is having plans prepared for the construction of a theatre on Penn Ave. A steam heating system will be installed in same. Total estimated cost, $250,000. Eugene De Rosa, 110 West 40th St., New York City, Archt. and Engr.

Md., Landsdowne—The Natl. Steel Rolling Co., 203 Keyster Bldg., Baltimore, will receive bids until June 10 for the construction of a 1 story, 70 x 140 ft. steel rolling mill. Electric motors will be installed in same. Total estimated cost, $100,000.

N. C., Youngsville—The city plans to construct an electric lighting station. Estimated cost, $20,000. J. R. Pearce, Mayor.

S. C., Paris Island—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., plans to improve the power plant here. Estimated cost, $75,000.

Ala., Florence—The United States Engineers Office, Wash., D. C., will receive bids until June 15 for furnishing and delivering 4 electric generators each of 25,000 kva. capacity with 5 exciters, etc.

La., Minden—The City Council will soon receive bids for the construction of a sewerage system and for the improvement of the electric light plant. Total estimated cost, $180,000. J. E. Carroll, Secy.

O., Akron—The Akron Grocery Co. will soon award the contract for the construction of a 5 story, 100 x 210 ft. warehouse. A steam heating system will be installed in same. Total estimated cost, $250,000. Harpster & Bliss, Archts.

O., Cleveland—The Bd. Educ. plans to construct a 2 story school at the Mayfield Township. A steam heating system will be installed in same. Total estimated cost, $250,000. S. Minor, Gates Mills, Clk.

O., Cleveland—The City plans to construct a 1 story, 60 x 110 ft. electric transmitting station on West 103rd St. and Western Ave. Estimated cost, $100,000. E. Shattuck, Agt. W. E. Davis, City Hall, Engr.

O., Cleveland—The city plans to construct a 1 story, 60 x 110 ft. electric transmitting station near Euclid Ave. and East 105th St. Estimated cost, $100,000. E. Shattuck, Agt. W. E. Davis, City Hall, Engr.

O., Cleveland — The Cleveland Graphite Bronze Co., 2906 Chester Ave., is in the market for a white steamer power plant with slide valves and pump, with or without boiler. New or used.

O., Cleveland—The Knight-Norris Gibbs Co., 1017 Euclid Ave., plans to build a 6 story commercial building on St. Clair Ave. and East 21st St. A steam heating system will be installed in same. Total estimated cost, $350,000.

O., East Cleveland (Cleveland P. O.)—The Natl. Lamp Co. of the General Electric Co., Nela Park, is having plans prepared for the construction of a 1 story boiler plant. Boilers will be installed in same. Total estimated cost, $100,000. G. H. Johnson, Nela Park, Archt. and Engr.

O., Warren—The Trumbull Cliffs Furnace Co., Rockefeller Bldg., Cleveland, is having plans prepared for the construction of a 1 story 600-ton capacity blast furnace here. Estimated cost, $1,000,000. Freyn Brassert & Co., 122 South Michigan Ave., Chicago, Engrs.

Ind., Elkhart—The Marathon Motors Export Co. is in the market for 4 air compressors, complete, to operate 6 drills and 2 air lifts to have a capacity of 5,000 lb.

Ind., Terre Haute — The Amer. Car & Fdry. Co. plans to build a power house at its plant on 10th and Crawford Sts., to replace the building recently destroyed by fire. Estimated cost, $20,000.

Mich., Detroit—John H. Kunsky, Madison Theatre Bldg., engaged C. H. Crane & E. G. Hiehler, Archts., Huron Bdg., to prepare plans for the construction of a 6 story, 155 x 250 ft. theatre and office building on Broadway and Madison Aves. Steam heating equipment and forced ventilating devices will be installed in same.

Mich., Detroit—John H. Kunsky, Madison Theatre Bldg., is having plans prepared for the construction of a 10 story, 100 x 155 ft. office building on Broadway Ave. Steam heating equipment will be installed in same. C. H. Crane & E. G. Kiehler, Huron Bldg., Archts.

Ill., Chicago—C. M. Garland, 1st Natl. Bank Bldg., is in the market for 750-1500 kw. mixed pressure turbine, direct connected, 3 phase, 60 cycle 2,300 volt generator, complete with switchboard, condenser and connections, to operate on high pressure steam at 150 lb. pressure and low pressure steam at 3 lb. gage. Turbine must be capable of carrying full load on either low or high pressure steam. One 300-400 kw., 2,300 volt, 3 phase, 60 cycle generator, direct connected to high pressure or turbine, either condensing or non-condensing.

Ill., Chicago—Sam and Lee Shubert Inc., 225 West 44th St., New York City, plans to build 2 theatres. A steam heating system will be installed in same. Total estimated cost, $500,000. Herbert J. Krapp, 116 East 16th St., New York City, Archt. and Engr.

Wis., Sheboygan — The city will soon award the contract for the construction of a 3 story, 100 x 150 ft. high school on North 9th and Jefferson Sts. Steam heating equipment including Kewanee heaters will be installed in same. Total estimated cost, $300,000. Childs & Smith, 64 East Van Buren St., Chicago, Archts. Noted March 16.

Ia., Fort Madison—The city will receive bids until June 9 for the construction of a sanitary sewerage system including 2 ejector pumping stations. Total estimated cost, $400,000. Burns & McDonnell, 402 Interstate Bldg., Kansas City, Mo., Engrs.

Minn., Buffalo—The village clerk will receive bids until June 4 for the construction of a deep well, water system, and a 14 x 20 ft. pump house including 2 pumps and motors to have a 250 gal. per min. capacity. Total Estimated cost, $60,000.

Minn., Minneapolis — The Minneapolis Sanatorium Hotel Co., 2716 Hennepin Ave., is having plans prepared for the construction of an 8 story sanatorium on Yale Pl. A steam heating system will be installed in same. Total estimated cost, $500,000. O. K. Westphal, 319 Kasota Bldg., Archt.

Minn., Olivia—The Bd. of Educ. received bids for the installation of a heating and ventilating system in the proposed 3 story, 63 x 150-ft. high school, from the Amer. Heating Co., 1813 Winter Ave., Superior, Wis., $22,490; Beck Eng. & Constr. Co., 1137 Plymouth Bldg., Minneapolis, $25,985; Heins & Byers, $26,755. Noted March 9.

Neb., Gordon—J. J. Olsen, City Clk., will soon award the contract for furnishing labor and additional machinery and equipment for a waterworks extension including one 160 hp. steam engine, uniflow type; one 80 hp. engine, two 120 hp. steam boilers; one 110 ft. steel smokestack; one 120 hp. and one 180 hp. true Diesel engines.

Mo., St. Louis—The city voted $68,000 bonds to construct a morgue on 12th St. A refrigeration plant will be installed in same. L. R. Bowen, City Hall, Engr.

Ark., Little Rock—The E. L. Bruce Co. is in the market for a new or used, 25 hp., 3 phase, 60 cycle, 440 volt motor.

Tex., Dallas—George C. Nimmons & Co., Archts., 120 South Michigan Ave., will soon award the contract for the construction of a 9 story, 160 x 300 ft. general merchandise building for the Sears, Roebuck & Co., Arthington and Homan Aves., Chicago. A steam heating system will be installed in same. Total estimated cost, $2,000,000.

Tex., Fort Worth—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., received only bid for the installation of deep well pumping equipment at the Helium Production plant here from Layne & Bowler, Rand Bldg., Memphis, Tenn., $23,000.

Wash., Cedar Falls—The City Council of Seattle has passed an ordinance appropriating $495,000 to complete the construction of the pipe line and a 15,000 kw. plant here.

Wash., Centralia—The Kane Pneumatic Shock Absorber Co., Fords Prairie, plans to construct a power plant which will generate from 750 to 1,500 kw. A mechanical stoker system will be installed in same. P. W. Kane, pres.

Wash., Puget Sound — The Bureau of Yards & Docks, Navy Dept., Wash., D. C., will receive bids until June 16 for the installation of auxiliary equipment and piping for the air compressor. Estimated cost, $60,000. Noted May 10.

Wash., Spokane—The Washington Water Power Co., 825 Trent St., plans to build a 37 mi. high tension power line from Long Lake to Chewelah. Estimated cost, $140,000.

Cal., Burbank—The Burbank Development Co., 206 West San Fernando St., is having plans prepared for the construction of 2 soap factory buildings on Verdugo Ave. Electric power and steam generating plants will be installed in same. Total estimated cost, $200,000. H. J. Knouer, 129 Story Bldg., Los Angeles, Archt.

H. T., Kuahua—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., and the Public Works Office, Navy Yard, Mare Island, Cal., will soon receive bids for the furnishing and installation of high pressure air piping system at the Naval Ammunition Depot, here. Estimated cost, $10,000.

Ont., Brampton—W. Treadgold, Engr., is receiving prices on the supply and delivery of a turbine pump with electric motor, etc. Total estimated cost, $35,000.

Ont., Fort William—The Bd. Educ. plans to build two 2 story schools. A steam heating and mechanical ventilating system will be installed in same. Total estimated cost, $290,000.

Ont., Kincardine — The Town Council plans to build a hydro electric power station. Estimated cost, $45,000. T. Flint, Eugenia Falls, Engr.

Ont., New Market—The town plans to install a 1,000 Imp. gal. per min. 3 stage centrifugal pump to have a 100 lb. pressure. Estimated cost, $7,000. E. James Co., 36 Toronto St., Toronto, Engr.

CONTRACTS AWARDED

Mass., Springfield — The United Electric Light Co., 73 State St., has awarded the contract for the contruction of a 3 story, 90 x 58 ft. sub-station on Carew and North Sts., to A. E. Stephens Co., 145 State St. Estimated cost, $100,000. Noted March 9.

Mass., Worcester — The Rogers Drop Forging Co., Frank St., has awarded the contract for the construction of a forge plant including a 1 story, 60 x 85 ft. sand blasting building, 46 x 50 ft. boiler house, etc., to the E. D. Ward Co., 82 Foster St. Total estimated cost, $125,000.

N. Y., Brooklyn—The Bd. Educ., 500 Park Ave., New York City, has awarded the contract for the installation of heating and ventilating apparatus in P. S. 97 on Stillwell Ave., near Av S, to W. J. Olvany, 177 Christopher St., New York City, at $66,500.

N. Y., Brooklyn—The Bd. Educ., 500 Park Ave., New York City, has awarded the contract for the installation of heating and ventilating apparatus in P. S. 100, on West 1st St. near Sheepshead Bay, to W. J. Olvany, 177 Christopher St., New York City, at $94,681.

N. Y., Brooklyn—The Dept. of Char s, Municipal Bldg., has awarded the con ct for furnishing all labor and material e- quired for the construction of an addi on to the refrigerator plant at the K s County Hospital, to P. F. Larkin, 429 st 56th St., New York City, at $9,467.

N. Y., New York—The Varick St. B s, Co., c/o Helme & Corbett, Archts. d Engrs., has awarded the contract for e construction of a 10 story, 65 x 175 ft. ffice building on Varick, Grand and Watts s., to the Turner Constr. Co., 244 Mad on Ave. A steam heating system will be n- stalled in same.

N. Y., Watertown — The Beebes Isl nd Power Corp., has awarded the contract or furnishing and installing hydraulic tu ine equipment, in connection with the propo ed development on the Black River, to the Wellman, Seaver Morgan Co., 7009 Cen al Ave., S. E., Cleveland, O., and electric generators, to the General Electric Co., River Rd., Schenectady.

Pa., Philadelphia — The Hurley Motor Co., Broad and Race Sts., has awarded the contract for the construction of a 15 story, 55 x 130 ft. office building, to William Steel & Sons Co., 16th and Arch Sts. A steam heating system will be installed in same. Total estimated cost, $750,000.

Md., Cumberland—The Crystal Laundry Co., Baltimore St., has awarded the contract for the construction of a 1 and 2 story, 130 x 284 ft. laundry, garage and power house, to W. J. Morley, 98 Bedford St. Total estimated cost, $200,000. Noted April 27.

Va., Bedford—The city has awarded the contract for the construction of a storage reservoir and probably 2 small pumping units, etc, to Diehl & Vance, Virginia Carolina Bldg., Norfolk.

S. C., Greenville—The Farmers & Merchants Bank has awarded the contract for the construction of a 16 story bank and office building, to C. T. Wills, 286 5th Ave., New York City. A steam heating system will be installed in same. Total estimated cost, $1,000,000. Noted April 6.

O., Canton—Schlemmer & Graber, 12th St., has awarded the contract for the construction of a 2 story, 60 x 153 ft. garage, to E. J. Landor Co., Renkert Bldg., at $101,100. A steam heating system will be installed in same.

Mich., Muskegon Heights (Muskegon P. O.)—The Bd. Educ. will build a 2 story, 250 x 250 ft. high school. Steam heating equipment will be installed in same. Total estimated cost, $400,000. Work will be done by day labor.

Ill., Chicago—The L. J. McCormick Corp., c/o Holabird & Roche, Archts., 114 South Michigan Ave., has awarded the contract for the construction of a 1 story, 100 x 120 ft. theatre on Dearborn and Randolph Sts., to the Longacre Constr. & Eng. Co., 127 North Dearborn St. A steam heating system will be installed in same. Total estimated cost, $1,000,000. Noted May 10.

Wis., Menasha—The Bd. Educ. has awarded the contract for the construction of a 2 story high school addition and power plant, to the C. K. Meyer & Son Co., 50 State St., Oshkosh. New boilers and blower fan will be installed in same. Total estimated cost, $95,000.

Ia., Glidden—H. W. Porter, Secy. of the Bd. of Educ., has awarded the contract for the installation of a heating and plumbing system in the proposed 3 story, 90 x 162 ft. school building to C. F. Rock Plumbing & Heating Co., St. Joseph, Mo., at $36,213. Noted May 10.

Minn., New Ulm—The city has awarded the contract for the construction of a 1 story, 40 x 90 x 90 ft. power plant, to J. G. Robertson, University Ave., St. Paul, at $145,399. Noted May 10.

Wash., Tacoma—The state has awarded the contract for the construction of a power and heating plant at the State Capitol here, to Albertson, Cornell Brothers and Simpson at $155,263.

Cal., El Segundo—The General Chemical Co., 25 Broad St., New York City, has awarded the contract for the construction of a group of factory buildings for the manufacture of sulphuric acid to the J. G. White Eng. Corp., 43 East Exch. Pl., New York City. A steam heating system will be installed in same. Total estimated cost, $2,000,000.

PRICES - MATERIALS - SUPPLIES

Electrical prices on following page are prices to the power plant by jobbers in the larger buying centers east of the Mississippi. Elsewhere the prices will be modified by increased freight charges and by local conditions.

POWER-PLANT SUPPLIES

HOSE—

	Fire	50-Ft. Lengths
Underwriters' 2½-in.		85c. per ft.
Common, 2½-in.		30%

	Air		
	First Grade	Second Grade	Third Grade
¼-in. per ft.	$0.60	$0.40	$0.30

Steam—Discounts from List

First grade..... 20% Second grade..... 30% Third grade....45%

RUBBER BELTING—The following discounts from list apply to transmission rubber and duck belting:

Competition..... 50% Best grade..... 20%
Standard..... 30–10%

LEATHER BELTING—Present discounts from list in fair quantities (½ doz. rolls):

Light Grade	Medium Grade	Heavy Grade
30%	25%	20%

RAWHIDE LACING
For cut, best grade, 25%, 2nd grade, 30%.
For laces in sides, best, 79c per sq. ft.; 2nd, 75c.
Semi-tanned: cut, 20%; sides, 83c per sq. ft.

PACKING—Prices per pound:

Rubber and duck for low-pressure steam	$1.00
Asbestos for high-pressure steam	1.70
Duck and rubber for piston packing	1.00
Flax, regular	1.20
Flax, waterproofed	1.70
Compressed asbestos sheet	.90
Wire insertion asbestos sheet	1.50
Rubber sheet	.50
Rubber sheet, wire insertion	.70
Rubber sheet, duck insertion	.50
Rubber sheet, cloth insertion	.30
Asbestos packing, twisted or braided and graphited, for valve stems and stuffing boxes	1.30
Asbestos wick, ½- and 1-lb. balls	.85

PIPE AND BOILER COVERING—Below are part of standard lists, with discounts.

PIPE COVERING		BLOCKS AND SHEETS	
Pipe Size	Standard List Per Lin.Ft.	Thickness	Price per Sq.Ft.
1-in.	$0.27	½-in.	$0.27
2-in.	.36	1 -in.	.30
6-in.	.80	1½-in.	.45
4-in.	.60	2 -in.	.60
3-in.	.45	2½-in.	.75
8-in.	1.10	3 -in.	.90
10-in.	1.30	3½-in.	1.05

85% magnesia high pressure..... List

For low-pressure heating and return lines { 4-ply ..... 50% off; 3-ply ..... 52% off; 2-ply ..... 54% off

GREASES—Prices are as follows in the following cities in cents per pound for barrel lots:

	Cincinnati	Chicago	St. Louis	Birmingham	Denver
Cup	8½	6.6	8½	8½	10.5
Fiber or sponge	8½	8.6	11@14	8½	13.75
Transmission	10	8.1	11@14	8½	12.5
Axle	...	4.8	5@ 5½	5	7.0
Gear	6½	6.1	6@ 7	4½	8.5
Car journal	12(gal.)	4.7	22@24	5	9.0

COTTON WASTE—The following prices are in cents per pound:

	New York			
	Current	One Year Ago	Cleveland	Chicago
White	11.00@15.50	13.00	16.00	11.00 to 14.00
Colored mixed	7.00@10.50	9.00 to 12.00	12.00	9.50 to 12.00

WIPING CLOTHS—Jobbers' price per 1000 is as follows:

	13½ x 13½	13½ x 20½
Cleveland	$55.00	$65.00
Chicago	41.00	43.50

LINSEED OIL—These prices are per gallon:

	New York		Chicago	
	Current	One Year Ago	Current	One Year Ago
Raw in barrels (5 bbl. lots)	$1.75	$1.59	$2.05	$1.78
5-gal. cans	1.78*	1.72	2.30	1.98

*To this *oil* price must be added the cost of the cans (returnable), which is $2.25 for a case of six.

WHITE AND RED LEAD—Base price per pound:

	Red				White	
	Current		1 Year Ago		Current	1 Yr. Ago
	Dry	In Oil	Dry	In Oil	Dry and In Oil	Dry and In Oil
100-lb. [illegible]	15.50	17.00	13.00	14.50	15.50	13.00
25- and 50-lb. kegs	15.75	17.25	13.25	14.75	15.75	13.25
12½-lb. kegs	16.00	17.50	13.50	15.00	16.00	13.50
1-lb. cans	18.50	20.00	15.00	16.50	15.00	15.00
5-lb. cans	20.50	22.00	16.00	17.50	16.00	16.00

500 lb. lots less 10% discount; 2000 lb. lots less 10–2½%.

RIVETS—The following quotations are allowed for fair-sized orders from warehouse:

	New York	Cleveland	Chicago
Steel ⅞ and smaller	30%	40%	35–10%
Tinned	30%	40%	35–10%

Boiler rivets, ½, ⅝, 1 in. diameter by 2 in. to 5 in. sell as follows per 100 lb.:

New York....$6.00 Cleveland...$4.00 Chicago...$5.37 Pittsburgh...$4.72

Structual rivets, same sizes:

New York....$7.10 Cleveland...$4.10 Chicago...$5.47 Pittsburgh...$4.82

REFRACTORIES—Following prices are f. o. b. works, Pittsburgh district:

Chrome brick	net ton	$75–80	at Chester, Penn.
Chrome cement	net ton	45–50	at Chester, Penn.
Clay brick, 1st quality fireclay	net M.	45–50	at Clearfield, Penn.
Clay brick, 2nd quality	net M.	40–45	at Clearfield, Penn.
Magnesite, dead burned	net ton	50–55	at Chester, Penn.
Magnesite brick, 9 x 4½ x 2½ in.	net ton	85–90	at Chester, Penn.
Silica brick	net M.	50–55	at Mt. Union, Penn.

Standard size fire brick, 9 x 4½ x 2½ in. The second quality is $4 to $5 cheaper per 1000.

St. Louis—Fire Clay, $45@$50.

Birmingham—Silica, $51 @ 55: fire clay, $45 @ 50; magnesite, $100; chrome, $100.

Chicago—Second quality, $25 per ton.

Denver—Silica, $18: fire clay, $12: magnesite, $57.50.

BABBITT METAL—Warehouse prices in cents per pound:

	New York		Cleveland		Chicago	
	Current	One Year Ago	Current	One Year Ago	Current	One Year Ago
Best grade	90.00	87.00	74.50	79.00	70.00	75.00
Commercial	50.00	42.00	21.50	18.00	15.00	15.00

SWEDISH (NORWAY) IRON—The average price per 100 lb., in ton lots, is:

	Current	One Year Ago
New York	$20.00	25.50–30.00
Cleveland	20.00	20.00
Chicago	21.00	16.50

In coils an advance of 50c. usually is charged.
Domestic iron (Swedish analysis) is selling at 12c. per lb.

SHEETS—Quotations are in cents per pound in various cities from warehouse; also the base quotations from mill:

	Large Mill Lots	New York			
Blue Annealed	Pittsburgh	Current	One Year Ago	Cleveland	Chicago
No. 10	3.55–6.00	7.12@8.00	4.57	7.55	7.02
No. 12	3.60–6.05	7.17@8.05	4.62	7.65	7.07
No. 14	3.65–6.10	7.22@8.10	4.67	7.70	7.12
No. 16	3.75–6.20	7.32@8.20	4.77	7.80	7.22
Black					
Nos. 18 and 20	4.15–6.30	8.50@9.50	5.30	8.20	7.80
Nos. 22 and 24	4.20–6.35	8.55@9.55	5.35	8.25	7.85
No. 26	4.25–6.40	8.60@9.60	5.40	8.30	7.90
No. 28	4.35–6.50	8.70@9.70	5.50	8.40	8.00
Galvanized					
No. 10	4.70–7.50	9.75@11.00	5.50	8.50	8.15
No. 12	4.80–7.60	9.85@11.00	5.55	8.60	8.20
No. 14	4.80–7.60	9.85@11.10	5.50	8.60	8.35
Nos. 18 and 20	5.10–7.90	10.10@11.40	5.90	8.90	8.65
Nos. 22 and 24	5.25–8.02	10.25@11.55	6.05	9.05	9.05
No. 26	5.40–8.20	10.40@11.70	6.20	9.20	9.20
No. 28	5.70–8.59	10.70@12.00	6.50	9.50	9.50

*For painted corrugated sheets add 30c. per 1000 lb. for 5 to 28 gage, 25c. for 19 to 24 gages; for galvanized corrugated sheets add 15c., all gages.

PIPE—The following discounts are for carload lots f. o. b. Pittsburgh; basing card of Jan. 1, 1919, for steel pipe and for iron pipe:

	Steel			Iron	
Inches	Black	Galvanized	Inches	Black	Galvanized
	BUTT WELD				
⅛, ¼, and ⅜	50½%	24%	¾ to 1¼	30½%	23½%
½	54½%	40%			
¾ to 3	57½%	44%			
	LAP WELD				
2	50½%	35%	2	32½%	18½%
2½ to 6	53½%	41%	2½ to 6	34½%	21½%
	BUTT WELD, EXTRA STRONG PLAIN ENDS				
⅛, ¼ and ⅜	48½%	26%	¾ to 1½	39½%	24½%
½	51½%	39%			
¾ to 1½	50½%	43%			
	LAP WELD, EXTRA STRONG PLAIN ENDS				
2	48%	37%	2	33½%	20½%
2½ to 4	51%	49%	2½ to 4	35½%	23½%
4½ to 6	50%	39%	4½ to 6	34½%	22½%

Stock discounts in cities named are as follows:

	New York		Cleveland		Chicago	
	Black	Galvanized	Black	Galvanized	Black	Galvanized
⅜ to 3 in. steel butt welded	40%	24%	40%	31%	54%	40½%
2½ to 3 in. steel lap welded	35%	20%	42%	27%	50%	37½%

Malleable fittings. Class B and C, from New York stock sell at list + 32%. Cast iron, standard sizes, net.

BOILER TUBES—The following are the prices for carload lots, f. o. b. Pittsburgh:

Lap Welded Steel		Charcoal Iron	
3½ to 4½ in.	40½	3½ to 4½ in.	15½
2½ to 3¼ in.	30½	3 to 3¼ in.	1
2¼ in.	24	2½ to 2¾ in.	+1
1¾ to 2 in.	19½	2 to 2½ in.	+16
		1¾ to 1⅞ in.	+29

Standard Commercial Seamless—Cold Drawn or Hot Rolled

	Per Net Ton		Per Net Ton
1 in.	$327	1¾ in.	$207
1¼ in.	267	2 to 2½ in.	177
1½ in.	257	2¾ to 3½ in.	167
1½ in.	207	4 in.	187
		4½ to 5 in.	207

These prices do not apply to special specifications for locomotive tubes nor to special specifications for tubes for the Navy Department, which will be subject to special negotiations.

ELECTRICAL SUPPLIES

ARMORED CABLE—

B. & S. Size	Two Cond. M Ft.	Three Cond. M Ft.	Two Cond. Lead M Ft.	Three Cond. Lead M Ft.
No. 14 solid	$104.00	$138.00	$164.00	$210.00
No. 12 solid	135.00	170.00	225.00	265.00
No. 10 solid	185.00	235.00	275.00	325.00
No. 8 stranded	285.	375.00	520.00	500.00
No. 6 stranded	400.(	500.00	560.00	.....

From the above lists discounts are:

	Net List
Less than coil lots	10%
Coils to 1,000 ft.	15%
1,000 ft. and over	

BATTERIES, DRY—Regular No. 6 size red seal, Columbia, or Ever-Ready:

	Each, Net
Less than 12	$0.45
12 to 50	.38
50 to 125 (bbl.)	.35
125 (bbl.) or over	.32

CONDUITS, ELBOWS AND COUPLINGS—These prices are f. o. b. New York with 10-day discount of 5 per cent.

	Conduit		Elbows		Couplings	
Size, In.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.
¼	97.01	103.18	24.20	25.26	2.65	8.10
⅜	128.48	136.82	32.20	33.65	8.92	7.42
1	189.92	202.26	47.14	49.80	12.73	14.58
1¼	256.96	273.05	60.02	63.26	16.56	17.50
1½	307.24	327.20	80.02	84.35	22.75	23.89
2	413.36	440.24	145.63	154.63	28.10	29.52
2½	653.57	699.60	240.00	253.04	37.35	39.36
3	854.67	910.20	640.22	674.78	53.35	56.23
3½	1,060.94	1,127.74	1,433.83	1,494.60	80.03	112.46
4	1,283.15	1,362.53	1,633.90	1,722.10	106.70	140.58

Standard lengths rigid, 10 ft. Standard lengths flexible, ½ in., 100 ft. Standard lengths flexible, ¾ to 2 in., 50 ft.

CONDUIT NON-METALLIC, LOOM—

Size I. D., In.	Feet per Coil	List, Ft.	
⅜	250	$0.05½	
½	250	.06	
¾	250	.09	
⅞	200	.12	
1	200	.15	Coils..... 40% off
1¼	150	.18	Less coils, 25% off
1½	100	.25	
1¾	100	.33	
1½	Odd lengths	.40	
2	Odd lengths	.55	

CUT-OUTS—Following are net prices each in standard-package quantities:

CUT-OUTS, PLUG

S. P. M. L.	$0.11	T. P. to D. P. S. B.	$0.24
D. P. M. L.	.11	T. P. to D. P. T. B.	.38
T. P. M. L.	.26	T. P. S. B.	.33
D. P. S. B.	.19	T. P. D. B.	.54
D. P. D. B.	.37		

CUT-OUTS, N. E. C. FUSE

	0-30 Amp.	31-60 Amp.	60-100 Amp.
D. P. M. L.	$0.33	$0.84	$1.68
T. P. M. L.	.48	1.20	2.40
D. P. S. B.	.42	1.05	.....
T. P. S. B.	.81	1.80	.....
D. P. D. B.	.78	2.10	.....
T. P. D. B.	1.35	3.60	.....
T. P. to D. P. D. B.	.90	2.52	.....

FLEXIBLE CORD—Price per 1,000 ft. in coils of 250 ft.:

No. 18 cotton twisted	$22.00
No. 16 cotton twisted	27.00
No. 18 cotton parallel	26.50
No. 16 cotton parallel	34.50
No. 18 cotton reinforced heavy	34.00
No. 16 cotton reinforced heavy	42.00
No. 18 cotton reinforced light	30.00
No. 16 cotton reinforced light	36.75
No. 18 cotton Canvasite cord	28.50
No. 16 cotton Canvasite cord	32.00

FUSES, ENCLOSED—

250-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.25
35-amp. to 60-amp.	100	.35
65-amp. to 100-amp.	50	.90
110-amp. to 200-amp.	25	2.00
225-amp. to 400-amp.	25	3.60
425-amp. to 600-amp.	10	5.50

600-Volt	Std. Pkg	List
3-amp. to 30-amp.	100	$3.40
35-amp. to 60-amp.	100	60
65-amp. to 100-amp.	50	50
110-amp. to 200-amp.	25	50
225-amp. to 400-amp.	25	50
450-amp. to 600-amp.	10	00
Discount: Less 1-5th standard package	30%	
1-5th to standard package	40%	
Standard package	52%	

FUSE PLUGS, MICA CAP—

0–30 ampere, standard package	$4.75C
0–30 ampere, less than standard package	6.00C

LAMPS—Below are present quotations in less than standard package quantities:

Straight-Side Bulbs Mazda B—				Pear-Shaped Bulbs Mazda C—			
Watts	Plain	Frosted	No. in Package	Watts	Clear	Frosted	No. in Package
10	$0.40	$0.45	100	75	$0.75	$0.80	50
15	.40	.45	100	100	1.10	1.25	24
25	.40	.45	100	150	1.55	1.70	24
40	.40	.45	100	200	2.10	2.30	24
50	.40	.45	100	300	3.15	3.40	24
60	.45	.50	100				12
				500	4.60	4.90	12
				750	6.50	6.90	8
				1,000	7.50	7.95	8

Standard quantities are subject to discount of 10% from list. Annual contracts ranging from $150 to $300,000 net allow a discount of 17 to 40% from list.

PLUGS, ATTACHMENT—

		Each
Hubbell porcelain No. 5406,	standard package 250	$0.24
Hubbell composition No. 5467,	standard package 50	.32
Benjamin swivel No. 903,	standard package 250	.20
Hubbell current taps No. 5638,	standard package 50	.40

RUBBER-COVERED COPPER WIRE—Per 1000 ft. in New York.

No.	Solid Single Braid	Solid Double Braid	Stranded, Double Braid	Duplex
14	$12.00	$16.00	$13.90	$28.50
12	13.25	15.70	18.05	30.70
10	18.30	21.00	23.85	41.50
8	25.54	28.60	32.70	56.77
6	.....	.....	51.40	.....
4	.....	.....	70.00	.....
2	.....	.....	101.80	.....
1	.....	.....	131.86	.....
0	.....	.....	160.00	.....
00	.....	.....	193.50	.....
000	.....	.....	235.20	.....
0000	.....	.....	288.60	.....

Prices per 1000 ft. for Rubber-Cozered Wire in Following Cities:

	Denver			Birmingham			St. Louis		
	Single Braid	Double Braid	Duplex	Single Braid	Double Braid	Duplex	Single Braid	Double Braid	Duplex
14	$19.50	$24.00	$39.50	$13.90	$20.90	$35.80	$15.32	.....	$36.73
10	28.92	33.12	65.52	26.10	35.50	59.40	24.38	.....	55.47
8	40.32	45.12	89.64	36.60	49.50	79.00	33.49	.....	.....
6	63.84	69.24	.....	60.10	67.25	.....	.....	.....	.....
4	.....	97.86	.....	.....	93.41	.....	.....	76.06	.....
2	.....	145.20	.....	.....	120.40	.....	.....	108.66	.....
1	.....	189.00	.....	.....	155.23	.....	.....	140.38	.....
0	.....	251.40	.....	.....	188.77	.....	.....	169.91	.....
00	.....	305.40	.....	.....	229.19	.....	.....	201.35	.....
000	.....	317.40	.....	.....	278.64	.....	.....	238.89	.....
0000	.....	451.20	.....	.....	338.41	.....	.....	286.42	.....

Pittsburg—23c. base; discount 50%. St. Louis—30c. base.

SOCKETS, BRASS SHELL—

¼ In. or Pendant Cap			⅜ In. Cap		
Key Each	Keyless Each	Pull Each	Key Each	Keyless Each	Pull Each
$0.33	$0.30	$0.60	$0.39	$0.36	$0.66

Less 1-5th standard package	+50%
1-5th to standard package	+20%
Standard package	—10%

WIRE, ANNUNCIATOR AND DAMPPROOF OFFICE—

No. 18 B. & S. regular spools (approx. 8 lb.)	55c. lb.
No. 18 B. & S. regular 1-lb. coils	56c. lb.

WIRING SUPPLIES—

Friction tape, ¾ in., less 100 lb. 60c. lb., 100 lb. lots	55c. lb.
Rubber tape, ¾ in., less 100 lb. 65c. lb., 100 lb. lots	60c. lb.
Wire solder, less 100 lb. 50c. lb., 100 lb. lots	46c. lb.
Soldering paste, 2 oz. cans Nokorode	$1.20 doz.

SWITCHES, KNIFE—

TYPE "C" NOT FUSIBLE

Size, Amp.	Single Pole, Each	Double Pole, Each	Three Pole, Each	Four Pole, Each
30	$0.42	$0.68	$1.02	$1.36
60	.74	1.22	1.84	2.44
100	1.50	2.50	3.76	5.00
200	2.70	4.50	6.76	9.00

TYPE "C" FUSIBLE, TOP OR BOTTOM

30	70	1.06	1.60	2.12
60	1.18	1.80	2.70	3.60
100	2.38	3.66	5.50	7.30
200	4.40	6.76	10.14	13.50

Discounts:

Less than $10.00 list value	+25%
$10 to $25 list value	+10%
$25 to $50 list value	+5%
$50 to $200 list value	—10%
$200 list value or over	—15%